

NOTE

Some charts and graphs were color-coded in the original document. While it has not been possible to reproduce these items in color, their equivalent values on the black-and-white scale are often distinct enough to convey the same information as the original colors.

November 1991

A Cahners Publication

R&D

Research & Development®

GOTCHA!!!

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R&D

The International Magazine of Research and Development

R&D FOCUS

GOTCHA!!!

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ABOUT THE COVER Forensic laboratories are becoming increasingly involved in drug testing. For more on this, see article on page 48.

R&D BUSINESS

Survey Reveals Monthly Changes in R&D

The confidence level that corporate executives have in their future R&D spending, employment stability, and capital spending is reflected in a new business index from Cahners Economics (CE), Newton, MA.

The index is based on 400 monthly interviews with marketing and management people in manufacturing, consumer products, construction, electronics, and computer sectors.

Respondents evaluate the economic environment of their businesses for the next three months and report

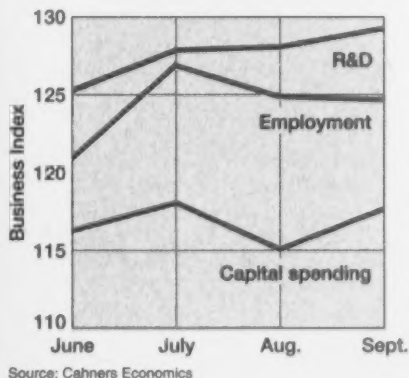
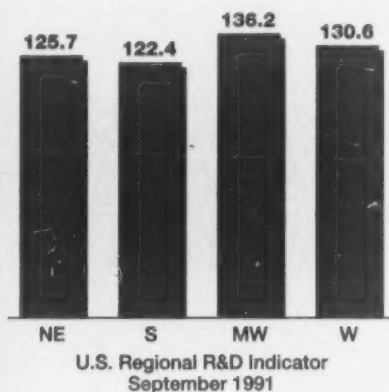
plans for changes in seven areas: capital equipment purchases, employment, inventories, marketing, new product introductions, and R&D.

Results from the first surveys reveal that spending for R&D and new product introductions increased steadily from June to September. Spending for capital equipment, marketing, and production was erratic during this period, but the average of all seven indexes in September was about 4% higher than that in June.

Subindex values for regional, company size, and industry groupings also are collected. Regional and industrial grouping indices reveal that corporate managers are confident that R&D spending will continue or improve in all areas of the country and in all industrial sectors.

—Tim Studt

Improving Economic Conditions Predicted



Corporate executives are confident that most aspects of their businesses are positive (indexes >100), but will spend more on R&D than equipment.

Strong Growth in Fluorescence



With 14.1% annual growth through 1995, fluorescence spectrophotometers are forecast to be the fastest growing market of all the molecular spectroscopy instruments, according to Strategic

Directions Intl., a Los Angeles-based management consulting firm.

Biological research is the most important application of fluorescence spectrophotometers, particularly for research-grade instruments.

Biotech Needs New Approval Approach

At least 132 biotechnology-based drugs currently are being developed by U.S. companies, a 63% increase over those being developed in 1988, according to a recent study by the Pharmaceutical Manufacturers Assn. (PMA), Washington, DC.

"Unfortunately, only three biotech drugs were approved by the U.S. Food and Drug Administration over the past 16 months and only 14 drugs were approved over the past nine years," says Gerald Mossinghoff,

president of the PMA. "This rate must be increased to keep up with our industry's growing research activities."

A whole new approach to FDA approval must be established to account for the multiple indications produced by biotech-based drugs, according to James Grant, CEO of T-Cell Sciences, Cambridge, MA.

Biotechnology Medicines in Development, is available from Communications Div., PMA, 1100 15th St., NW, Washington, DC 20005. □

New Programs Begin For EC's Framework

The third generation of the European Community's (EC's) R&D Framework Program runs through 1994 and includes several new research programs.

In addition to established programs in information technologies and energy, new programs in the environment, telecommunications, and biotechnology are being established.

The Framework Program has a \$2.3 billion budget, which becomes available during late 1991 or early 1992. About \$150 million is allocated for telecommunications, \$165 million for environmental research, and \$65 million for biotech research.

The environmental program includes research studies in global

change, environmental monitoring, economic and social aspects of environmental issues, and technological risks of environmental policies.

The biotech program will cover the period 1992 to 1996. It will complement an existing program that ends in 1993, but will have more emphasis on basic biology. The program is open to all organizations in EC member states. The European Commission provides for 50% of the total cost of for shared-cost projects and 100% of the marginal costs for universities.

Additional information from the Commission of the European Communities, Brussels, 010/322-235-1111. □

Business continues

Superconducting Materials Find Product Niches

Processing problems have slowed development of high- T_c materials, but application-specific products are starting to emerge.

By Tim Studt, Senior Editor, R&D Magazine



They may not be fully understood. They may involve complex processing and take several days to heat treat properly. But high- T_c superconducting materials, in both bulk and thin-film forms, are starting to be developed into real-world products.

Some product applications, such as liquid level sensors for cryogenic nitrogen or magnetic bearings, are not readily identified with the zero resistivity inherent in superconductors. Many other applications, though, are directly relatable, such as coils and electric motor windings, infrared sensors, and interconnecting leads to existing low- T_c MRI (magnetic resonance imaging) coils.

The three primary high- T_c materials that researchers are working with are Y-Ba-Cu-O (95 K T_c), Bi-Pb-Sr-Ca-Cu-O (108 K), and Tl-Ca-Ba-Cu-O (125 K). A vanadium oxide-based material with a 130 K T_c has been developed at Hitachi's Superconductivity Research Center, Tokyo, but it is unstable and loses its superconductivity after a few days when exposed to air.

Development of these materials into thin films for sensors and electronic applications, while slow, has been relatively steady, without the major engineering problems that the bulk materials have had to overcome. Development of the bulk materials is considered essential for large-scale commercial and industrial uses.

Bulk high- T_c problems involve the inherent brittleness of the ceramic components, which makes them hard to form into wire. They also have a limited current carrying capacity, and they exhibit "flux creep," which expends electrical energy by opposing lines of magnetic force.

"However, even these obstacles to commercializing superconducting

technology are rapidly falling away," says Gregory Yurek, president and CEO of American Superconductor Corp. (ASC), Watertown, MA. The current-carrying limitation of high- T_c materials is caused by a "weak link" between adjacent crystals of the superconducting ceramics. Each crystal conducts electricity without resistance when cooled, but the crystal interfaces don't conduct as efficiently.

Researchers at ASC control the weak-link problem by filling hollow silver tubes with blended bismuth-based superconducting powders and then pulling the tubes through draw dies to fine-wire sizes. The wires are then baked to convert the blended powders into ceramic superconductors. Why this eliminates the weak-link problem is not yet fully understood.

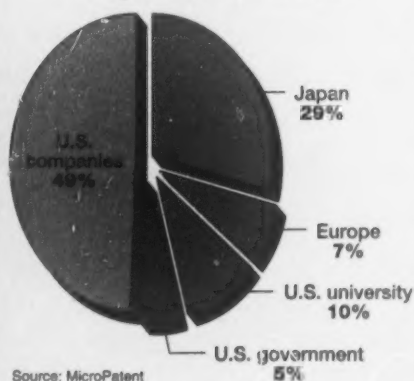
Working with Reliance Electric Co., a Cleveland-based electric motor manufacturer, ASC recently demonstrated a 25-W, 2,500-rpm DC motor containing superconducting coils made from bismuth-based wires. The liquid-nitrogen-emersed high- T_c coils were powered by a 0.5-A current. "This is the first motor using superconducting coils that produces a usable power output," says Yurek.

Development of this motor was funded by the Electric Power Research Institute, Palo Alto, CA. It follows earlier work involving superconducting coils that have been cycled from room temperature to 77 K and continue to perform satisfactory after operating for more than 17 months.

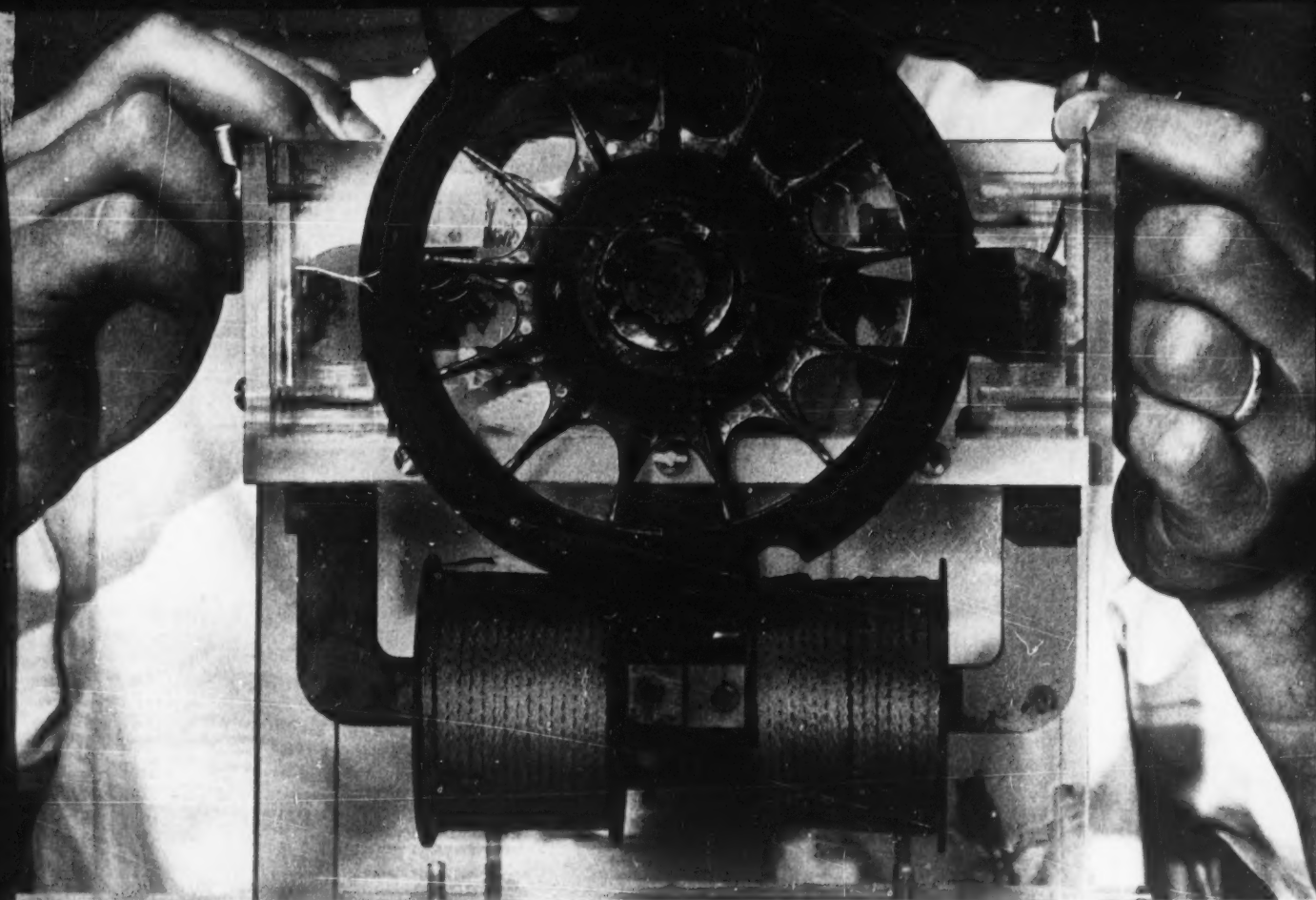
Operating high- T_c materials in liquid nitrogen is convenient and less involved than operating in the liquid helium (4 K) environment required for low- T_c products. However, in high- T_c materials containing bismuth, the

HTS Patents Warm Up Competition

U.S. patents issued in 1990



U.S. companies hold a strong lead in the patents issued for high- T_c materials, apparatus, and processes.



Technician for Reliance Electric examines the power leads for a 25-W DC fan motor constructed with two high- T_c superconducting field coils.



Conductus's high- T_c bolometer, packaged in a liquid nitrogen dewar, detects far-IR radiation with greater sensitivity than any other IR detector operating at or above 77 K. Applications include ecological and climatological studies.

weak-link effect disappears at 20 K.

This also is not yet understood, but researchers are evaluating the use of high- T_c materials at 20 K, where the materials are less likely to lose their superconducting properties in a changing operating environment. Additionally, cryocoolers that refrigerate to 20 K are commercially available for less than \$20,000, compared to helium liquefiers that cost more than \$200,000. "Being able to flip a switch on a cryocooler is an important step in making superconductor technology commercially feasible," says Alexis Malozemoff, vice president of R&D at ASC.

The flux-creep problem was resolved by introducing small defects in the superconducting bulk material. Defects increase the maximum current a superconductor can sustain, particularly in external magnetic fields. They do so by "pinning," or preventing the motion of magnetic field lines that would otherwise produce electrical resistance.

Current methods for introducing defects into high- T_c materials involve

Processes for developing superconducting integrated circuits have been demonstrated by several companies.

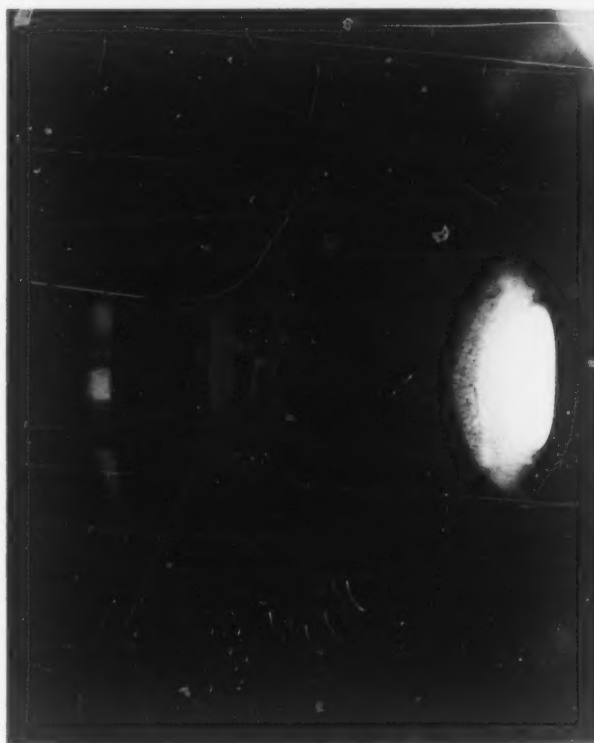
adding impurities which become randomly distributed during processing. Researchers at IBM T.J. Watson Research Center, Yorktown Heights, NY, Oak Ridge (TN) National Laboratory, Argonne (IL) National Laboratory (ANL), Ames (IA) Laboratory, and Iowa State Univ., Ames, have developed a technique that uniformly distributes pinning defects into crystals of Y-Ba-Cu-O.

Defects are introduced into the crystals by bombarding them with a 580-MeV beam of tin ions. The resultant defects are 20 atoms wide and aligned with the direction of the beam. At 77 K, the researchers obtained a critical current density of $450,000 \text{ A/cm}^2$ in a magnetic field of 1 tesla on the modified materials. It should be noted that the crystal interfaces of these Y-Ba-Cu-O materials can sustain only small amounts of current before electrical resistance appears.

Wires made of superconducting materials are becoming commercially available in various current-carrying capacities and in more than 1,000-m lengths. Most of these wires have relatively low critical currents, from 2,000 to $10,000 \text{ A/cm}^2$.

"The heat treatments for these wires get very specific, and companies will not divulge the details so they don't lose their individual competitive advantages," says Roger Poeppel, director of ANL's Superconductivity Pilot Center, one of three such centers established by the U.S. Dept. of Energy to facilitate superconductor technology transfer. A silver-clad bismuth-based superconducting tape for high-field (20 tesla) magnets that is being developed by ANL and Superconducting Products Co., St. Charles, IL, entails extensive heat treating.

"Heat treatments each take about a week, so it takes many months just to do a few trials," says Poeppel. This wire exhibits a critical current of $40,000 \text{ A/cm}^2$ at 4 K. Production doesn't present overwhelming obstacles, once the processing characteris-



High-temperature substrate heater (red disk in picture) was developed to uniformly deposit high- T_c materials, but can be used for other material deposition processes.

tics are defined, Poeppel says.

"Our immediate goal is to make a small coil where the total conductor length is 250 mm," says Poeppel. He estimates that it will take a few more years before this particular product is ready for production.

Argonne researchers also worked with researchers at Westinghouse Electric Corp., Pittsburgh, to develop bulk high- T_c leads that can replace conventional copper leads for transmitting electricity from room-temperature power supplies to low- T_c devices operating at 4 K, such as the coils in MRI systems.

The copper leads used in current low- T_c MRI systems heat up as current is passed through them. The heat is then conducted to the liquid helium refrigerant, causing it to boil off. Collecting and recycling this helium vapor adds considerable cost to conventional systems.

The high- T_c leads developed by Argonne and Westinghouse carry a record 2,000 A without conducting heat back to the liquid helium. They con-

sist of 20 rectangular bars fabricated from a composite of silver and Y-Ba-Cu-O.

One of the first commercially available high- T_c products also used Y-Ba-Cu-O materials as a principle component in the fabrication of a cryogenic liquid level sensor by researchers at Argonne and Illinois Superconductor, Evanston, IL. The sensor consists of two wires with a measurable resistance. When the wires are immersed in a cryogenic liquid, the exposed portion retains its resistance and the immersed portion loses its resistance. The overall resistance then can be calibrated to the liquid level.

This product has extensive applications in medical life sciences, biotechnology, and cryopreservation industries. A similar stand-alone system has recently been announced by Lake Shore Cryotronics, Westerville, OH.

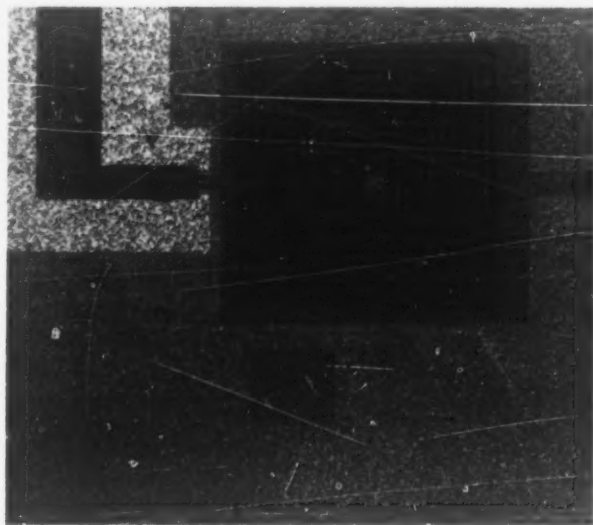
While there is much new in the bulk high- T_c arena, steady progress has also been made in thin films.

Three companies—Biomagnetic Technologies Inc., San Diego, Bellcore, Red Bank, NJ, and Conductus, Sunnyvale, CA—all recently announced processes for manufacturing Josephson junctions from thin-film Y-Ba-Cu-O superconductors. All the processes are repeatable, inexpensive, and use conventional semiconductor fabricating techniques.

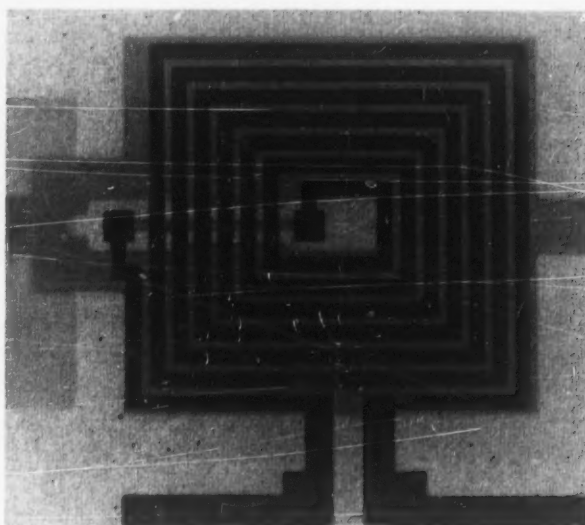
Josephson junctions are the superconducting equivalent of the transistor, which is the basis for any future superconducting circuits. They are formed from two weakly coupled superconductors that switch from the superconducting state to the nonsuperconducting state in about a trillionth of a second.

Researchers at Conductus fabricated the first integrated circuit, a SQUID magnetometer, containing devices made from high- T_c superconductors. SQUIDs (superconducting quantum interference devices) are the most sensitive magnetic field devices known. They operate by converting hard-to-measure magnetic flux into

High- T_c infrared detectors are up to 50 times more sensitive than current room-temperature devices.



Integrated SQUID (superconducting quantum interference device) and flux transformer made with a seven-layer epitaxial process containing three high- T_c layers.



The process used in making this five-layer high- T_c integrated SQUID magnetometer and flux transformer has been used to deposit up to 15 insulating and superconducting oxides.

easy-to-measure voltage. Conductus's SQUID sensor consists of a superconducting loop containing two Josephson junctions.

The high sensitivity of Conductus's SQUID is due to a superconducting flux transformer that has five- or 10-turn coils, coupled to a single-turn 10-mm-dia sensing loop.

"This circuit contains seven layers of material, making it the most complex circuit ever fabricated from high- T_c materials," says John Rowell, president and CEO of Conductus. "We can currently deposit 15 layers of epitaxial oxides, both high- T_c superconducting and insulating, plus a silver contact layer. These circuits demonstrate all the elements and techniques required to build integrated circuits for signal processing and digital applications."

Conductus's fabrication process uses conventional semiconductor lithography to pattern each layer and laser ablation to deposit the Y-Ba-Cu-O films on sapphire substrates.

Josephson junction devices also have been fabricated from bismuth-based high- T_c materials using low-temperature chemical vapor deposition methods by researchers at Fujitsu, Kawasaki, according to a report in the *Nikkan Kogyo Shimbun*, a Japanese newspaper.

Thin films of high- T_c Y-Ba-Cu-O also are being used as far-IR detectors (wavelengths $>20\ \mu\text{m}$) in bolometer

devices packaged in a liquid nitrogen dewar.

A bolometer is a device that measures small amounts of radiation by determining the changes of resistance in a conductor caused by changes in its temperature. The detector has up to 50 times the sensitivity of current room-temperature detectors. Applications include chemical laboratory spectroscopy, strategic defense, space-based environmental, ecological, and climatological studies.

There are a large number of additional thin-film applications for which products are not yet available, but for which prototypes have been demonstrated. Passive microwave (MW) devices are one application area that offers a near-term market for high- T_c electronics. The low-loss characteristics of superconductors enable MW engineers to design ultra-high-frequency devices with improved sensitivity, higher resolution, and with lower power consumption.

High- T_c interconnects for integrated circuits is another strong application area. Both Hitachi, Tokyo, and IBM's Research Division, Yorktown Heights, NY, are working on projects to operate their CMOS (complementary metal-oxide semiconductor) DRAM circuits at 77 K. Operating in this environment cuts the gate delays in half and therefore can nearly double the speed of a computer.

An offshoot of thin-film research is the development of equipment to apply the films. For the most part, high- T_c thin-film materials have been fabricated with existing semiconductor-based equipment. However, specialty equipment that had to be developed is now available for use in other areas.

In order to apply uniform films of high- T_c materials, for example, a heater was developed that allows precise and stable temperature control in environments from UHV to atmospheric pressures. The 7.5-cm heater from U.S. Inc., Campbell, CA, operates up to 950 C and holds the temperature stable to $\pm 2\ \text{C}$.

The current component design and fabrication stage of the Superconducting Supercollider project and the increasing popularity of MRI systems are the biggest technology drivers for high- T_c materials.

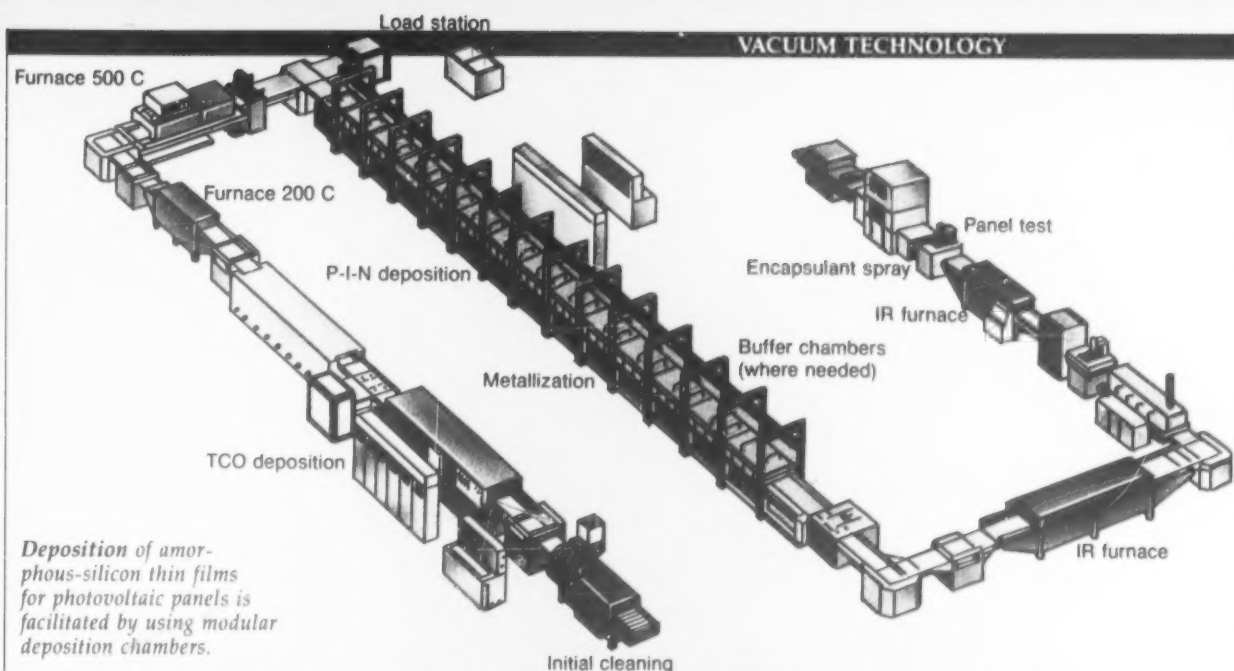
Continued improvements in wire performance and fabrication techniques and in thin-film processing should further the growth in high- T_c materials and further products throughout this decade.

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In-Line Vacuum Deposition Needs Special Solutions

Depositing large thin-film areas of amorphous silicon requires development of a continuous process for high throughput.

By J. Grant Armstrong, MKS Instruments, Pawan Bhat, Materials Research Group Inc., and Scott Brown, Glasstech Solar Inc.

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THE AUTHORS

J. Grant Armstrong is a regional manager at MKS Instruments, Boulder, CO. **Pawan Bhat** is president of Materials Research Group Inc., Wheatridge, CO, and previously was director of technology at Glasstech Solar Inc., Golden, CO. **Scott Brown** is president of Glasstech Solar Inc.

Uniform deposition of large-areas of amorphous-silicon thin films, such as those used in flat-panel displays and photovoltaic (PV) panels, is difficult enough in a laboratory batch operation. But the process and yield demands needed to scale up to production levels add yet another level of problems.

These problems include develop-

ment of a vacuum system for pumping across a series of chambers, continuous operation of various deposition processes, and minimization of defects in the films.

The most common method to deposit amorphous-silicon thin films is plasma-enhanced chemical vapor deposition (PECVD). Since a major factor in production improvements comes from the process equipment, systems must be designed for continuous processing, automatic operation, and minimum downtime.

Ideally, raw material should go in one end and a finished product should come out the other. This concept leads to a continuous in-line configuration consisting of a series of PECVD chambers with load locks at each end.

Severe demands are placed on the vacuum pumping systems for these systems. Each chamber must achieve good base pressures, handle high gas loads, provide rapid pumpdowns, and accommodate frequent cycling.

Our systems use mechanical pumps

and blowers for high-pressure processes and turbopumps for high-vacuum applications. Holding those vacuums while running the PECVD processes continuously with few defects is the key to obtaining high net throughputs.

Just one defect in the amorphous-Si thin film of a flat panel display can render an entire panel unusable. One inoperative transistor can create a line across the panel or a visible dark spot on an active matrix panel.

Similarly, the overall performance of amorphous-Si PV panels, which can be as large as 1.2×2.4 m, can be severely degraded by a 5- μ m defect, since the lowest performance cell in a series of cells dictates the performance of the entire panel.

Fast-acting rectangular gate valves isolate each of our in-line chambers and open only long enough, typically about 5 sec, to allow the 1- to 5-mm-thick glass substrates to move through.

Buffer chambers between some

A few parts per million of one dopant in the wrong layer of an amorphous-silicon thin film could make a PV cell unusable.

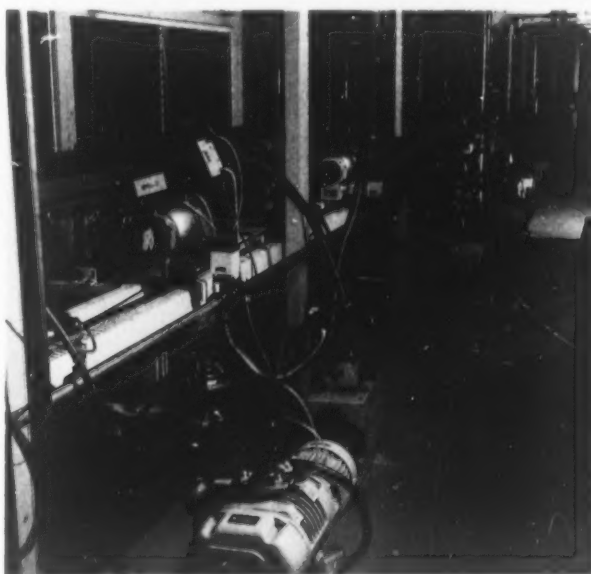
deposition processes limit cross-contamination of dopant gases to adjacent chambers. Conventional in-line systems do not use buffer chambers—the processes in each chamber stop when substrates are transported through the system.

Fabricating a PV panel requires three consecutive PECVD steps with buffer chambers. The first step is a 100-Å-thick deposition of p-doped amorphous-Si. The second is a 3,000-Å intrinsic amorphous-Si layer, and the third is a 200-Å n-doped amorphous-Si layer.

A few parts per million of a dopant, such as phosphorous or boron, in the wrong layer of these films could render the entire PV cell unusable.

As the substrate nears the end of the first deposition process, a gate valve opens, and the substrate moves into a buffer chamber. Just before this valve opens, the buffer chamber pressure is equalized to that of the first deposition chamber. As the substrate moves through the buffer chamber, contaminating gases are removed and the pressure is equalized to that of the next process chamber.

To maintain a continuous process, pressure measurement and control are critical elements in this system. We



Turbomolecular pumps (spherical housings) provide 10^{-7} torr for plasma-enhanced chemical vapor deposition in this in-line continuous deposition system for fabricating PV panels.

use temperature-regulated Baratron capacitance manometers to measure pressures from 0.1 to 1 torr.

To ensure that process gases do not diffuse from one chamber into another when a gate valve opens, the adjoining chambers must be at the same pressure. Even a pressure difference of 10 mtorr could cause process gases to poison a buffer chamber, or cause the buffer gases to interfere with an active plasma in an adjoining chamber.

Since the gate valves are open only about 5 sec, the pressure control system must react quickly to achieve the needed pressure. Exhaust throttle valves are used to control the chamber pressures, since these devices provide a stable control and respond to pressure changes in a few seconds.

This valving system also ensures that the process gases have enough residence time in each chamber to react with each other and the substrate, by allowing gas flows to be set upstream and pressures to be set with the downstream throttle valve.

To minimize contamination from background gases, low base pressures of H_2O , O_2 , N_2 , and C are required. This dictates using specific materials to fabricate the equipment. Stainless steel is used wherever possible, although Al and Cu can be used in

some situations. Metal-sealed CF vacuum flanges are used to minimize leaks or permeation of gases through O-rings and metal-sealed VCR fittings are used in gas lines.

Thermal mass-flow meters and controllers are used to control up to eight gases flowing into each chamber. A proprietary gas distribution system uniformly distributes gases over the substrates.

The chambers, pumping systems, and radio-frequency-powered plasma electrodes were designed to confine plasmas to localized deposition areas. This confinement minimizes deposition outside the desired area.

Interaction of the plasma with the PECVD chamber walls can cause substrate contamination where dop-

ing gases are used, but this can be avoided by changing gas sources.

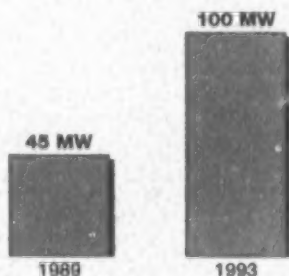
High-vacuum gages monitor base pressures and must tolerate many cycles from low to high pressures in an in-line system. Process chemistries that use corrosive gases are especially hard on these gages.

Hot-filament gages have been used with some success. However, future systems may employ cold-cathode gages to improve gage lifetimes. Partial-pressure instruments are placed at key points in the system to monitor the processes and provide diagnostics.

For the most part, large-area process systems can use readily available standard components. Equipment manufacturers have built, or plan to build, cluster tools or continuous in-line systems. Additional design considerations include design of transport systems that withstand more than 300 °C and materials for electrodes. Many of these issues have been addressed by manufacturers, but more work needs to be done.

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Sunny Days Ahead for Photovoltaic Panels



Source: PV News

More than 22% annual growth forecast in worldwide shipments of PV modules is driving development of new applications for amorphous silicon thin films.

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R&D

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AIR POLLUTION MODELS

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Corporation of the Year:
Asea Brown Boveri

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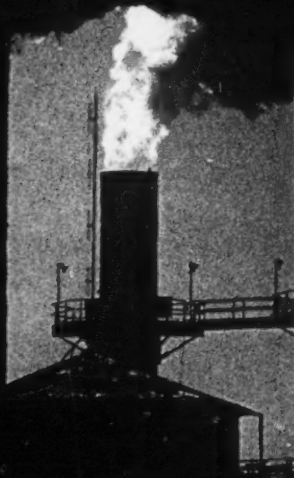
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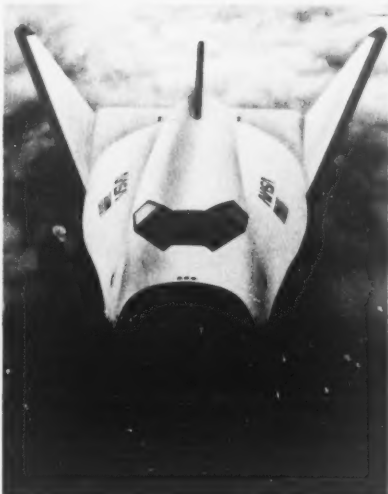
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Making Air Pollution Models Fit Closer 24

Improvements in air monitoring and data processing capabilities are increasing the reliability of emission predictions.

Asea Brown Boveri—A Model For Global Management 30

R&D Magazine's top corporation has internal contradictions. It's global yet local, centralized yet decentralized. That's why it works.



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Salute to French Technology II 43

In France, it's 'haute-tech.' Elf's R&D goes beyond oil. Europe's HDTV is on its way. It's all in the packaging. High-speed plane requires global alliance. R&D yields concrete results. Sun, sea, sand—and science. If it paints your nails, lifts your rocket, it could be SNPE's.



French Technology II, page 43

SALUTE TO FRENCH TECHNOLOGY II

PRODUCT APPLICATIONS

STM Reveals Structure Of Fullerene Films 38

Using an STM in high vacuum, researchers analyzed the growth characteristics of C₆₀ and C₇₀ films.

ABOUT THE COVER Emission control is improving, thanks in part to better modeling. The inset photo is from Pacific Northwest Laboratory. See article, page 24.

R&D BUSINESS

Japanese Companies Return Total R&D Growth to Double-Digit Figures

The latest figures for industrial and governmental Japanese R&D reveal a growth rate of 11.2% for FY1989, the first time growth exceeded 10% since 1985, according to data released by the Japanese Management & Coordination Agency (MCA), Tokyo.

This growth rate should remain at this level over the next few years, according to a study of the MCA report by the Japan Economic Institute (JEI), Washington, DC. Current R&D proposals for Japan's governmental FY1992 R&D budget, which traditionally go through only minor modifications, request a 6.4% increase for the Science and Technology Agency to \$4.1 billion and a 3.4% increase for the Ministry of International Trade and Industry (MITI) to \$2 billion. These increases equal or exceed the FY1989 increases.

The Japanese government's share of total R&D has continued its decade-long drop to only 18.6% of total funding in 1989, from 20% in 1988.

Governmental R&D has seen only modest changes over the past decade (high of 8% in 1987). The double-digit growth rates are primarily a function of rapid industrial R&D growth, which is forecast to experience contin-

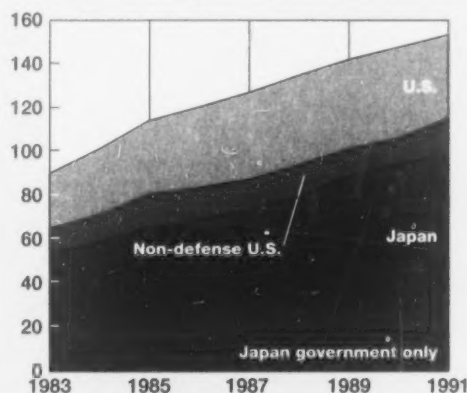
ued increases. The JEI study also revealed a Japanese corporate trend to concentrate more of its R&D on development and applied research and less on basic research.

The FY1992 budget proposals reveal double-digit growth requests for research in space technology (10% increase for development of the Japanese module for the U.S. space station), human genome (67% increase partially for a computer link to Johns

Hopkins Univ., Baltimore), and global environment (22% increase mostly for MITI's Research Institute of Innovative Technology for the Earth, set to open in 1992). □

No Letup in R&D Funding Growth

R&D funding (billions of dollars)



Source: U.S. National Science Foundation
Japan Management & Coordination Agency

Combined industrial and government R&D spending in Japan and the U.S. has been growing at \$5 billion to \$6 billion/yr over the past six years.

Engineering Status—Shortage or Not?

Demographic studies over the past five years revealed fewer students going into engineering and increasing numbers of senior engineers retiring. This led the National Research Council (NRC), Washington, DC, to predict an engineering shortage in the U.S. by the end of the 1990s. However, new data reflecting slow economic growth, defense budget cutbacks, and increased offshore sourcing of R&D, lower the outlook for engineering demand, according to Alan Fechter, executive director of the Office of Scientific and Engineering Personnel at the NRC.

"There's no strong sense of crisis at the present time," says Fechter. However, he does express concern about the disappointed people who went into engineering expecting a shortage, only to graduate and find that there were no jobs available. □

Cautious Growth In Electronic R&D

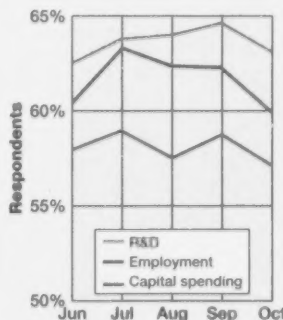
Uncertainty in the electronics industry led companies to cut back on their R&D spending in 1990, according to a recent study by *Electronic Business* magazine. Overall R&D spending by

Replacement Drives AA Growth



The market for atomic absorption (AA) spectrophotometers, a mature technology dependent on replacement sales, will grow 5% annually to \$296 million in 1995, according to Strategic Directions Intl., a Los Angeles-based consulting firm.

AA instruments are used to identify trace elements in the parts per billion range. Graphite furnace AA instruments are used to monitor metals in environmental samples.



Source: Cahners Economics

R&D Confidence Dips

Corporate executives have lost a little confidence in their ability to maintain R&D efforts, according to a survey by Cahners Economics, Newton, MA.

In October, only 62.9% of the 400 companies interviewed in CE's monthly survey said that their R&D, employment, and capital investment would remain stable or increase over the next few months.

R&D BUSINESS

the top 100 U.S. companies grew by only 5.3%, the third consecutive drop from the industry's growth peak of 22.9% in 1987.

R&D spending of the top 100 companies as a percent of sales and as a

Top 10 Electronics R&D Spenders

	R&D as % sales	1990 R&D spending*
1 Cypress Semicond.	24.7%	\$56
2 Integrated Device	19.9	42
3 Advanced Micro	19.2	204
4 Cadence Design	18.4	43
5 Ashton-Tate	17.2	40
6 Mentor Graphics	17.1	74
7 Applied Materials	17.1	97
8 Analog Devices	16.6	80
9 VLSI Technology	16.5	54
10 Cray Research	16.0	128

* millions

Source: Electronic Business

R&D spending increases averaged 14.9% in 1990 for the top electronic firms. The industry average of 5.3% was down from 1989's 10.6% average increases.

percent of net profits, while still positive, both dropped from the record high levels posted in 1989.

Lower R&D spending growth reflected the lower sales, profits, and market expectations of the electronics industry over the past three years, according to John Gawalt, a science resource analyst at the National Science Foundation, Washington, DC.

R&D growth is not expected to return to the high levels experienced in 1987 and 1988 in the near future. However, Cahners Economics forecasts a healthy sales upturn in early 1992, but notes that a cautious attitude still pervades the industry. □

Economic Outlook At An Economic Price

Cahners Economics is making available its 1992 *Economic Outlook* that includes macroeconomy forecasts, demographic and regional trends, and projections for more than 40 manufacturing, construction, and service sectors.

For a copy, send a check for \$21 (normally \$75) to cover postage and handling to: Cahners Economics, PO Box 59, New Town Branch, Boston, MA 02289. □

Baldrige Awards Go To Smaller Firms

The winners of this year's Malcolm Baldrige Quality Award have several things in common: they all were started less than 20 years ago, they all are involved in the manufacture of electronic equipment, and they all are considerably smaller than the corporate giants, such as IBM, General Motors, and Westinghouse, who won the award in the past.

The 1991 awards, managed by the National Institute of Standards and Technology, Gaithersburg, MD, were given to Solecron, San Jose, CA, Zytec, Eden Prairie, MN, and Marlow Industries, Dallas. The largest of these (Solecron) has \$265 million in sales; while Zytec has \$50 million and Marlow \$12 million in sales.

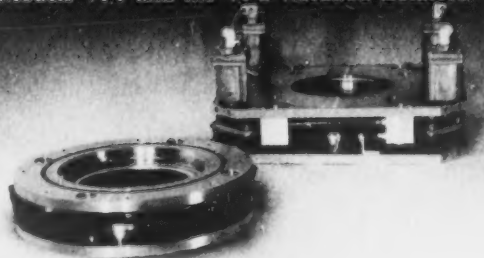
The awards program, established by Federal legislation in 1987, has been criticized in the past for a policy of self-nomination, implying that large companies had an advantage over smaller companies because of the amount of time and money that they could put into an entry. Critics have also charged that the awards program lacks a clear definition of what quality is and how it can be judged. R&D

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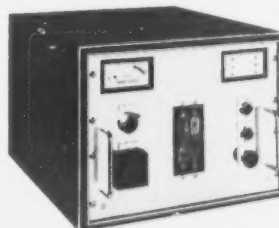
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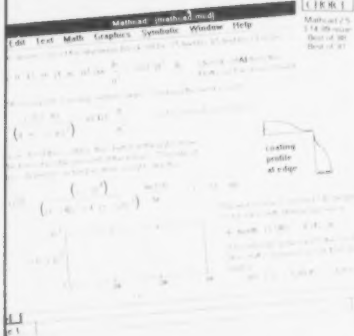
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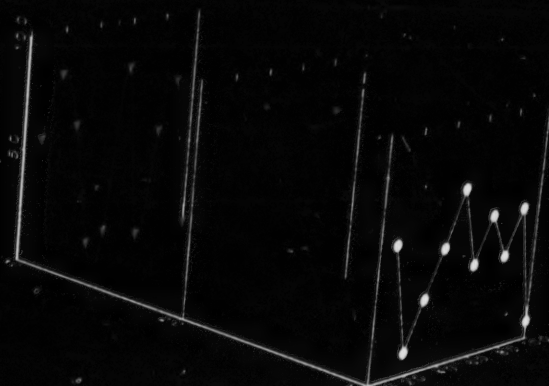
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ABOUT THE COVER Notebook-size personal computers that easily fit in your briefcase now have most of the performance capabilities of desktop models. Notebook shown is a color display model from Sharp. The display graphic is from Trimetrix. See the article, page 36.

R&D BUSINESS

Biotechnology Firms Face Obstacles From Trade and Regulatory Concerns

Biotechnology firms in the U.S., while currently the undisputed technical leaders of the almost 20-year-old industry, face critical bottlenecks which may hinder their future competitiveness, according to a recent U.S. Office of Technology Assessment (OTA) report.

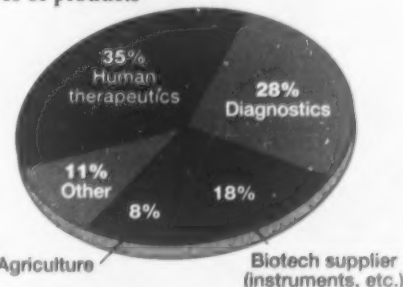
Despite being industry leaders, most U.S. biotech firms still have no sales and have been losing money since their inception. Only about 20% of U.S. biotech firms were profitable in 1990, while most are still several years away from a positive cash flow position.

One reason for the lack of profitability is the capital-intensive nature of product development: prior to product commercialization, some companies dedicate nearly 65% of all expenses to R&D. As much as \$5 billion to \$10 billion may be needed to develop the 100 biotech products currently in human clinical trials, according to the OTA study. However, many leading firms have high liquidity and can generate cash once product revenues start to flow.

Competitiveness issues facing U.S. companies include fair-trade practices, protection of intellectual property, the

Boom in BioTech Products Spurs Sales Growth

Types of products



Total sales



Source: Ernst & Young

Biotech firms focus on pharmaceuticals because more capital is available for them than for food or agriculture, due to the prospect of greater markets.

regulatory climate, and tax policies. To date, the U.S. R&D tax credit has been of little use to most firms because they are not profitable enough to generate a credit.

Many new biotech firms will face mergers and acquisitions as they try to find sources of working capital. While the OTA study found insufficient evidence for concern about for-

eign acquisitions, it recognized that the high cost of capital in the U.S. may put U.S. firms at a disadvantage in the long term.

FDA approval of biotech products was one item noted as being "inadequate to provide expeditious approval of important new drugs." Since the report was issued, however, the White House Competitiveness Council announced major streamlining changes in the FDA's drug approval process.

Despite all these problems, the OTA study still maintains that biotechnology is likely to be the principal scientific driving force for the discovery of new drugs and therapeutic chemicals in the 21st century.

—Tim Studd

Technical, Business Success Go Together

Technology leads business success when companies know how to manage technical resources, find commercial applications, and execute product, process, and quality improvements sooner than their competitors, according to William Howard, Jr., a senior fellow at the National Academy of Engineering (NAE), Washington.

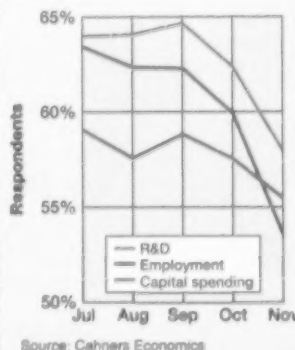
Howard was chairman of the NAE committee responsible for "Profiting From Innovation," a recently published report. Here the committee discusses the organizational and management challenges that appear in commercializing new products. These challenges include managing joint technical programs, integrating technical efforts, nurturing product cham-

Strong Growth for Elemental Analyzers



The market for elemental analyzers is forecast to grow 8.5% annually through 1995 to \$230 million, according to Strategic Directions International Inc., a Los Angeles-based consulting firm.

The environmental segment of the elemental analyzer market is growing more than 11% annually, while the metals and other segments are growing at a slower pace of less than 7% per year.



Source: Cahners Economics

R&D Slide Continues

Corporate executives continued to lose confidence in their ability to maintain R&D efforts, according to a survey by Cahners Economics, Newton, MA.

Only 57.9% of the 400 companies interviewed in CE's November survey said their R&D would remain stable or increase over the next few months. Employment and capital spending had similar declines.

tioning, polystyrene and polyethylene insulating foams, and other applications.

Changes are also taking place in the electronics industry, where for decades CFCs were used as cleaning solvents because of their stability and compatibility with most materials. But stability is also a main problem of CFCs: They are so stable they cannot be easily extracted from the atmosphere.

No-Clean fluxes from Alpha Metals Inc., Jersey City, NJ, eliminate the need for excessive rinsing of printed circuit boards and resulting wastewater treatment, the company says. The No-Clean technique leaves almost no residue on boards.

One of the company's fluxes is halide-free and rosin/resin-free with a 2.1% solids content. Other Alpha Metals fluxes have 2.2% and 4.4% solids levels.

"Our challenge was to find organic materials that remove copper, lead, and other metal oxides from circuit boards and component surfaces," says Alpha Metal's John Stevenson, product manager of assembly chemicals. "Two to three years ago, traditional fluxes contained 30% to 40% solids. Today we rely on organic acids and materials that volatilize at soldering temperatures to reduce solids content. This process has resulted in totally gaseous products that leave virtually zero residue."

Too much residue can result in ionic contaminants that lower surface insulation resistance of the boards. The small amount of residue left on the No-Clean boards also eliminates



Invention Offers a Different Angle on Tilt Control

Inventor Michael Summerfield demonstrates his Tilt Coupling, a leveling device that won two technology awards in Britain. Unlike other devices, the coupling can be set to a specific angle of tilt in less than 10 sec and has just one control for adjustment and locking.

The coupling uses two flat rings coupled by a hollow universal joint, with a pair of toothed wedge-shaped

cams and a slip ring between them.

The rings are able to tilt to an angle of 20 deg relative to each other in all directions, but they are retained in rotationally the same position.

The device has applications in control mirrors and laser lens systems, telescope mounts, satellite dishes, x-ray tables, surveying, and filming.

More information: Circle 360 on the Reader Service Card.

problems during automatic pin testing procedures. Extensive residue can form insulating pads on boards, and during testing, the system might detect defects where there are none.

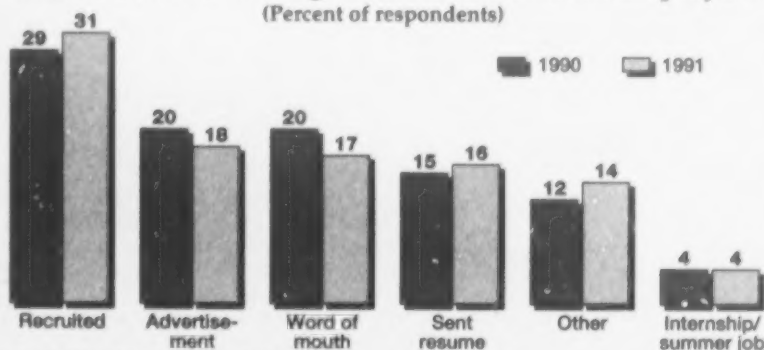
Another company, Zenon Environmental of Burlington, Ontario, is testing a membrane-based vapor permeation CFC recovery process that concentrates CFCs in liquid form. The

process, developed primarily for refrigeration, pharmaceuticals, ink, and specialty chemicals, was created to minimize the damaging effects of organic vapors produced by industrial processes that involve volatile hydrocarbons. Released into the atmosphere, such vapors and contaminants help create photochemical smog.

—Joyce Anne Oliver

How Scientists and Engineers Found Current Employers

(Percent of respondents)



Source: R&D Magazine Career Satisfaction Survey

The means by which researchers found jobs were fairly consistent among respondents to R&D Magazine's 1990 and 1991 Career Satisfaction Surveys. A complete analysis of results from the 1991 survey will appear in a future issue.

New Mobile Phones Use Infrared Light, Avoid the Airwaves

Cellular systems have had a revolutionary impact on the telephone industry, but telecommunications companies continue to search for more effective concepts.

The most innovative approach might come from infrared technology. A wireless pocket phone, invented by Light Ideas, Encino, CA, and recently demonstrated by British Columbia Telephone (an affiliate of GTE), offers what some experts call "crystal clear" transmission with greater privacy than cellular equipment.

"Many new concepts have been reported in recent years for wireless ac-

How Much Will It Cost To Run Your Lab in '92?

Global competition is forcing R&D managers to increase their budgets during the tough times of a double-dip recession.

By Tim Studd, Senior Editor, R&D Magazine

Recessions are like in-laws: They always arrive before you are ready for them, and they always hang around longer than you thought they would.

Most economists had predicted the U.S. economy would be in a recovery by now. The delay has put many R&D managers in a dilemma because of the need to stay profitable while developing new products.

The lingering recession also throws a curve at R&D budget planners, who no longer are quite sure how well their budget and cost predictions will hold up in this year's declining economy.

Despite this economic shakiness, managers of industrial, government, university, and nonprofit research centers are still optimistic about their spending plans for 1992, according to a recent survey of research managers



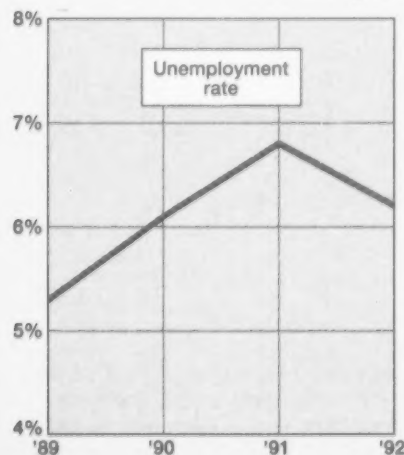
by R&D Magazine. More than 80% of the survey respondents indicated that they would maintain or increase their R&D spending in 1992. Only 16.5% of the R&D managers queried said that they would decrease their research spending this year (see accompanying chart).

Most research managers are confident that a recovery will still occur in 1992. They feel they have to maintain their present research efforts to ensure continued competitiveness in a global economy.

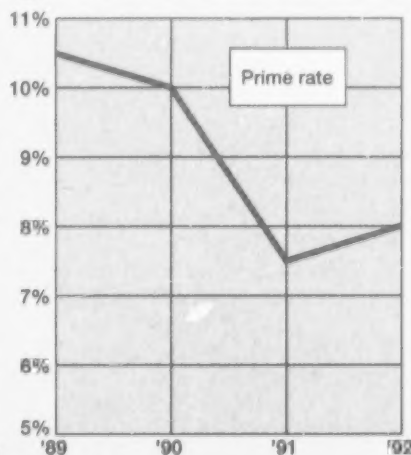
Additionally, with interest rates the lowest they've been in the past 10 years, the financing of research is as inexpensive as it is going to get. Current forecasts for interest rates indicate they will increase by the end of 1992 (see accompanying charts).

The lower U.S. financing costs now

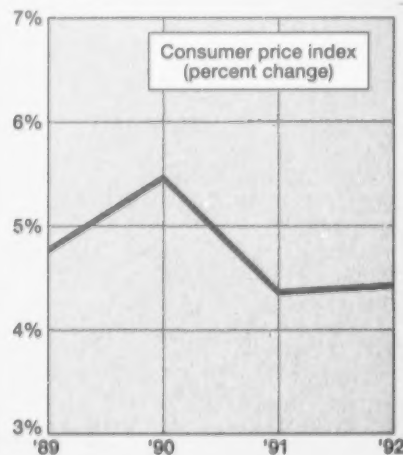
Deepening Recession Affects Economic Growth



The recession increased U.S. unemployment through the end of 1991, but CE forecasts improvement in 1992.

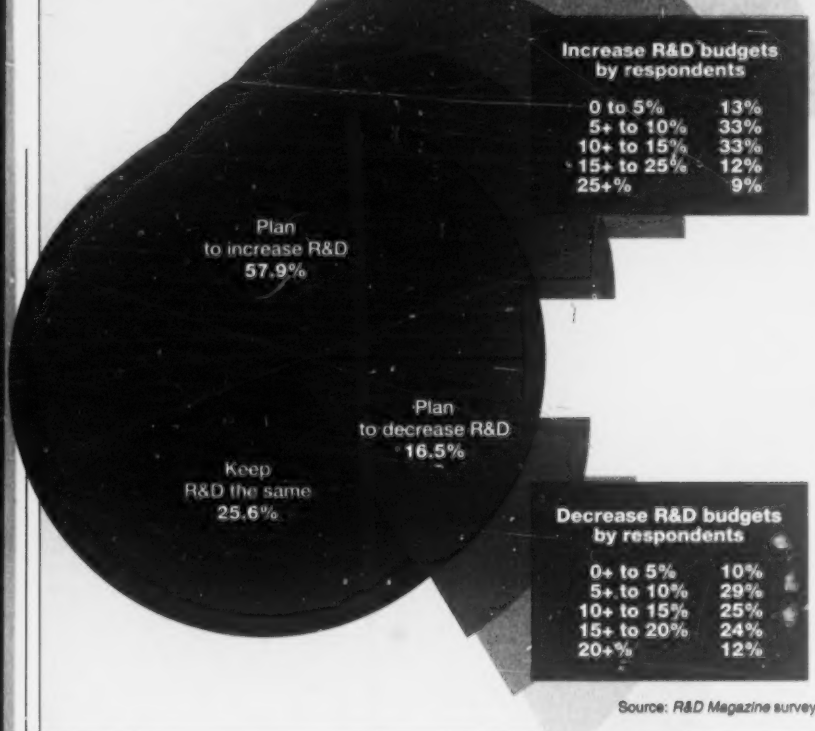


Steady drops in the prime rate over the past three years should make capital more available to U.S. firms.



CE does not forecast any major changes over the next several years in the current level of the Consumer Price Index.

Recession Fails to Dampen Corporate R&D



More than 80% of the R&D managers in a recent R&D Magazine survey said they will increase or maintain the current level of their R&D budgets in 1992.

approach and sometimes beat those of foreign firms, such as those in Japan. U.S. companies can now afford to invest more in equipment and wait longer for a payback on capital projects. U.S. firms were handicapped during the 1980s with financing costs that were twice those of companies in Japan and Germany.

The size of the research budget in-

creases indicated in the R&D Magazine survey also was encouraging, considering the state of the economy. On average, research managers said they would increase their 1992 budgets by more than 13% over their 1991 budgets. Nearly 9% of the respondents indicated that they would increase their budgets by more than 25%.

When asked what were the limiting

factors to even larger research spending increases, the managers almost universally responded that they were experiencing slow sales and narrow profit margins.

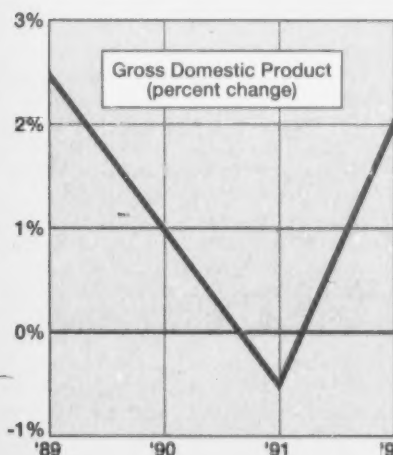
"Our budget is financed via profits; therefore, profit is a limiting factor on budget growth," says one industrial research manager.

"We're in a new product introduction cycle, so current development costs are impacting sales and subsequent profits," says another. "This will change in 1992 when our new products are introduced and revenues increase, thus financing our R&D increase."

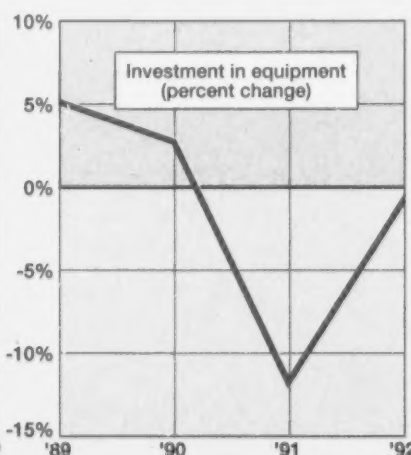
Governmental deficits are another limiting factor for Federal and state researchers. "The miserable state financial situation is a serious limiting factor on our research efforts," writes a New York state researcher.

Despite these limitations, there is a general confidence in future research spending that cuts across all sections of the U.S. and all sizes of companies, according to the survey results. Average budget increase predictions range from 10.2% for research organizations in the western U.S. to 15.9% for southern U.S. centers.

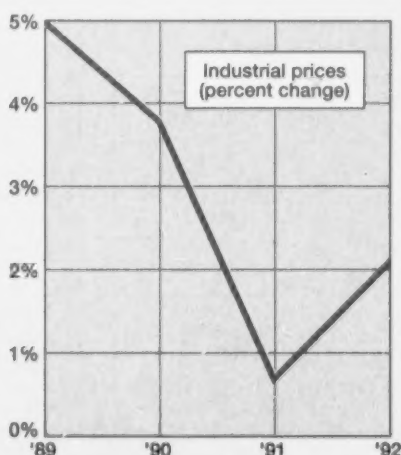
Similarly, respondents from organizations with less than 50 employees said their budgets would increase an average of 18.1% (the highest average increase), while organizations with 500 to 1,000 employees predicted in-



GDP statistics have replaced those of GNP, because they more accurately reflect the domestic U.S. economy.



The recession caused capital investment to drop off in 1991 with little improvement forecast for 1992 by CE economists.



Industrial prices only will see moderate increases in 1992, according to a forecast by the Laboratory Products Assn.

'Costs for installing equipment in new research laboratories will see large increases in 1992,' says one supplier.

creases of 8% (the lowest average increase).

A section of *R&D Magazine's* research funding survey also inquired about the makeup of R&D budgets. Salaries make up the largest portion of R&D spending in 1992, according to the survey, consuming an average of 47.3% of an organization's budget. Overhead, which includes facilities and support services, makes up the next largest amount with a 19.3% portion. Capital equipment (12.3%), supplies and consumables (11.5%), and miscellaneous items (9.6%) fill out the remainder of the research budget.

What will happen to the costs of these research budget components in 1992 and how will they affect the net level of research? For these answers, we contacted research managers and laboratory suppliers who responded with a list of both increases and decreases across the different sectors (see accompanying charts).

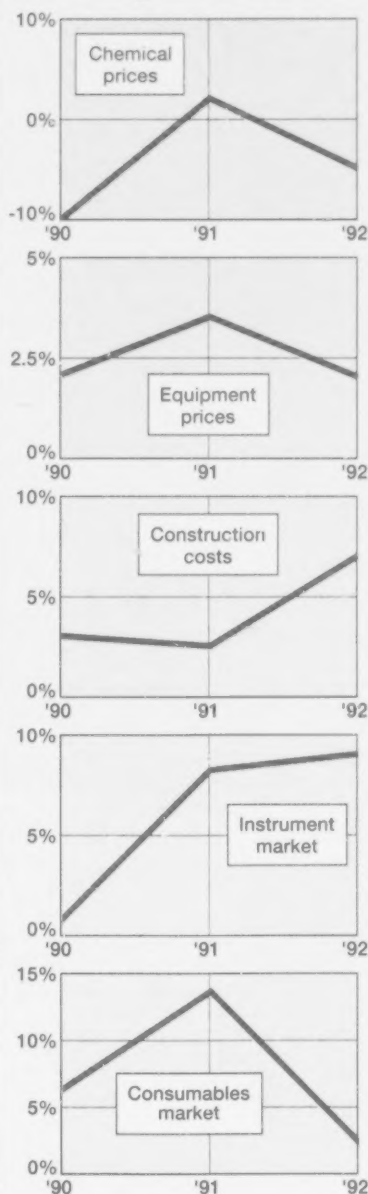
"R&D costs are governed by the same conditions that drive the rest of the economy, such as those that determine the cost of living," says James Serum, R&D manager for Hewlett-Packard analytical product group, Avondale, PA. "The primary governing effect on R&D is increases in the costs for salaries, supplies, and capital."

R&D Magazine's latest salary survey reveals that researchers' salaries increased in 1991 at a slightly higher rate than inflation, but increased benefits costs held back take-home increases. The current recession and continued pressure from global competitors to maintain lean staffing levels will keep the lid on salary demands in 1992.

The guiding trend for salary increases is the inflation rate, which in 1991 was about 4.3%. It is forecast to be 4.4% in 1992, according to Kermit Baker, chief economist at Cahners Economics, Newton, MA.

One area where research costs are forecast to experience substantial price increases is that of new laboratory construction. "There is a large amount of current renovation and new construction of research laboratories," says a product manager at a laboratory casework supplier. "While equipment costs, such as fume hoods and cabinets, will follow standard inflationary increases of the raw materials to make them, installation cost in-

Laboratory Economics Change Directions



Percent changes in constant dollars
Source: Cahners Economics
Laboratory Products Assn.
R&D Magazine

The prices for many products used in the laboratory will drop in 1992 while the cost of actually building a laboratory will increase, following several years of strong demand for mainly biotech labs.

creases are forecast to far outpace the inflation rate."

The heavy investment in R&D demanded by pharmaceutical and biotech companies is driving the demand for this new laboratory construction. The long-term research requirements of new products for these industries will keep demands and costs high for several years, according to the laboratory casework supplier.

Trying to estimate a general cost increase for laboratory instruments is meaningless because the performance improvements in new equipment and equipment upgrades trivialize comparisons. Instrument suppliers that were interviewed stated that in situations where totally identical instruments are involved, price increases will not exceed the inflation rate. But those cases represent a very small portion of their overall business.

"There is not a lot of emphasis on increasing prices of existing equipment in a down economy," says Michael Duff, vice president of public affairs at the Scientific Apparatus Makers Assn., Alexandria, VA. "Every three years there is a new generation of new products and system upgrades that changes the complexion of the market."

In other instrument-related areas, such as vacuum apparatus, price increases are a little easier to forecast because the product does not undergo periodical changes. Price increases in vacuum equipment are generally forecast to remain at their present levels throughout 1992.

"There was a major price increase in the cost of stainless steel in 1990," says one supplier of vacuum products. "But the recession and market pressure will keep prices stable in 1992."

On the other hand, chemicals used in the lab may cost you less in 1992. With low energy costs and few supply pressures foreseen, chemical prices in 1992 will moderate from the abnormally high prices seen in 1991, according to Julie Handelman, an economist at Cahners Economics. "The Gulf Crisis forced a dramatic price rise in industrial chemicals early in 1991," says Handelman. "However, prices started to plunge during last summer and are expected to end 1992 4.7% lower than in 1991."

The slow recovery from the current "moderate" recession has damped what might have been aggressive re-

'Research spending for biotechnology is likely to increase 9% in 1992, adding to 1991's 7% increase,' says Copeland.

search growth in some industrial areas. However, industrial research growth in the high-tech electronics, biotech, and computer areas will be the drivers in overall research growth (see accompanying box).

Biotech research is being driven by increased Federal funding, recently announced speedups in the FDA regulatory process, and recent diagnostic advances. "Research spending for biotechnology is likely to increase 9% in 1992, adding to the 7% increase seen in 1991," says William Copeland, president of Copeland Economics Group, Stamford, CT. As biotech companies turn to the production of FDA approved products, increased revenues will allow research increases of 11.7% in 1993, he says.

Growth in research spending in the computer industry is being severely hampered by a decline in sales. "In 1991, U.S. factory shipments of computers and office equipment declined 2.6%, the first negative year since 1986, says economist Handelman. "This industry will not exhibit any sustained recovery until mid-1992."

Costs for restructuring and downsizing will cut into the bottom line of computer makers, with only 7.2% sales growth forecast for 1992. IBM, for example, recently announced its intent to eliminate another 20,000 jobs, which brings to 55,000 the number of positions it has cut in the past two years. Research spending for computer equipment is forecast to increase 6.5% in 1992, according to a study performed by Schonfeld Associates, Lincolnshire, IL. IBM is still forecast to increase its research spending by 8.5% in 1992, although part of that will involve research with strategic partners.

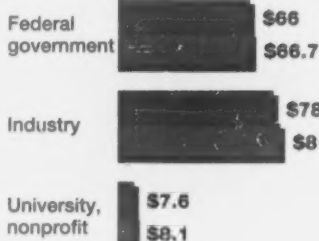
R&D spending increases forecast by Schonfeld include:

- 8.8% in the aerospace industry fueled by both commercial and continued defense contracts;
- 8.9% in the chemical industry;
- 7.3% for semiconductor manufacturers;
- 6.4% for plastics manufacturers;
- 14% in the pharmaceutical industry;
- 9% for communications equipment companies.

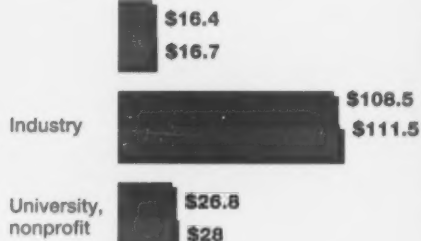
A potential loser in the current economic recession is university research. "Education is hard hit by state budget cuts and a lower level of funding overall," says a Laboratory Products Assn.

Total U.S. R&D Growth Slows in 1992

Who pays for the research



Who does the research



■ 1991 ■ 1992

Source: U.S. National Science Foundation, R&D Magazine

Total U.S. expenditures on research and development are expected to reach more than \$156 billion in 1992, a 3% increase from the 1991 level stated by the U.S. National Science Foundation. After adjusting for 1992's predicted inflation rate of 4.4%, this figure represents nearly a 1.5% decrease in real R&D spending.

This decline marks the third consecutive year that R&D spending has dropped in real terms. Some of this can be attributed to a decrease in defense-related government research. While defense research, development, test, and evaluation declined 7% in 1991, these will increase a little over 1% in actual dollars in 1992, according to U.S. Dept. of Defense forecasts. Substantial decreases in defense-related research won't start to show up until 1993.

Only university and nonprofit research are forecast to experience real-dollar research spending increases in

1992, with a 7.3% increase in sourcing of research and with a 4.7% increase in actual research performed.

The federal deficit does not appear to be limiting the size of research expenditures at other government agencies. This may not hold true for long, since the deficit is forecast to increase from 1991's \$250+ billion level to more than \$350 billion in 1992, before decreasing back to \$250 billion in 1993, according to Congressional Budget Office estimates.

The Dept. of Energy is forecast to increase its spending by 13% to \$6.2 billion. The National Institute of Health will up their budget 7% to \$8.9 billion in 1992, while the National Science Foundation will see an 18% increase to \$2.6 billion.

Most government-funded research is performed externally, especially that for DOD, NSF, and NIH. About 60% of NIH research is performed in universities.

study performed by Coalesce Corp., Monte Sereno, CA. "Grants are more competitive and their purposes are more directly controlled, eliminating some research areas that formerly received federal funds."

With the deficit budgets of Federal, state, and city governments, a recovery of university research support is not expected for several years, according to the study. The obvious effect of diminishing governmental support for university research is increased costs for corporate contracts to cover the fixed laboratory and researcher expenses.

Most economists still agree that a slow recovery will occur by the third

quarter of 1992, especially in an election year. Costs of running your research lab will probably not exceed the inflation rate and may, in many cases, decrease. Despite the fact that corporate profits are down substantially, it's not as bleak a picture for R&D laboratories as it is for most other corporate and governmental departments.

R&D

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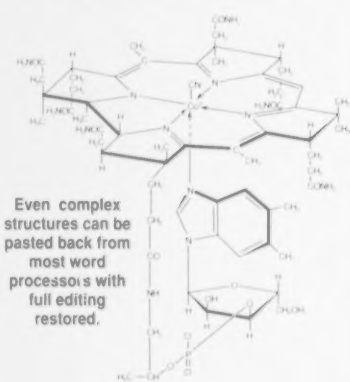
Susie Pruett and
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JACS '91, p. 2342



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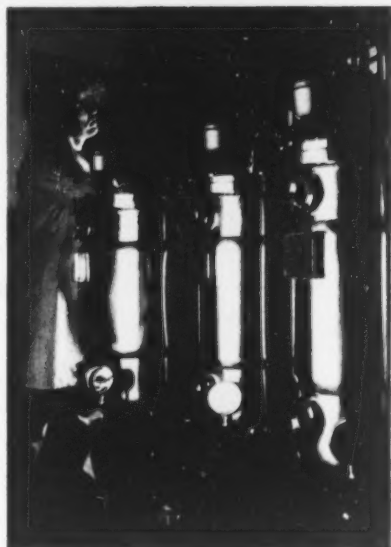
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ABOUT THE COVER IR imaging allows Spectra-Physics Inc. to optimize design and quality control of its Brewster window, a critical laser component. Photo: AGEMA Infrared Systems Inc.

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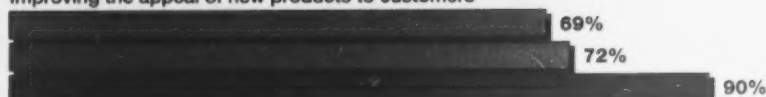
Study Reveals Views on Product Innovation

Product Innovation Goals Differ

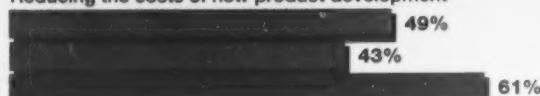
Getting new products to the market on time



Improving the appeal of new products to customers



Reducing the costs of new product development



Respondents indicating they were devoting a high level of effort

Source: Arthur D. Little Inc. ■ U.S. ■ Europe ■ Japan

Few respondents to a product innovation study indicated their efforts were low in any area; however, Japanese respondents indicated the highest levels.

There are strong regional variations in how corporate managers view their product innovation efforts, according to a recent study by Arthur D. Little Inc., Cambridge, MA.

"Japanese managers are devoting more effort to more areas of product innovation than either U.S. or European companies who responded to the survey," says Ranganath Nayak, a senior vice president at Arthur D. Little and leader of the study. "Japanese companies have concentrated on understanding the product innovation process for a long time."

More than 700 respondents contributed to the study, 50% from Europe, 40% from the U.S., and 10% from Japan. Some of the response differences could be attributed to the way Japanese managers reply to a question, says Nayak. Japanese managers "take a broader, more systematic view of the product innovation process, and are more willing to take bold steps to improve their products rather than rely on small incremental improvements."

The management systems that the different regional companies put in place also are different. "A Mazda

plant in Mexico, for example, has less automation and fewer workers than U.S. automotive plants," says Nayak. "The management system put in by the Japanese allows the plant to be run by the average person, whereas U.S. or European companies often try to put in 'superman' managers."

This was reflected in the study where U.S. and European managers rated the lack of skilled leaders as their greatest barriers to product innovation. Japanese managers pointed to "poorly communicated objectives for new products and insufficient attention to product specifications" as their greatest barriers to innovation.

U.S. and European companies need to put in more structured procedures to match Japanese companies' competitiveness, says Nayak. For a copy, 617/864-5770. —Tim Studt

In Recession, Focus On Core Units

Decentralizing and downsizing are common actions that many companies will take during a recession. Forward-thinking companies should restructure to improve their competitive position when the economy improves, not just to reduce costs, says Thomas Boyce, a consultant for SRI International, an R&D consulting firm in Menlo Park, CA.

Less than half of the firms that restructure to reduce costs, increase their competitive advantage, or take advantage of technical advances actually achieve their goals, according to recent studies.

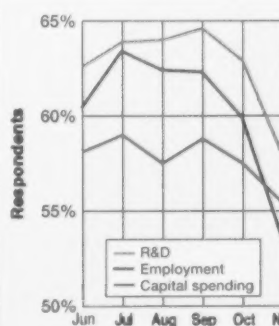
Business continues

Users Switching to Hyphenated GC



The U.S. market for hyphenated gas chromatography (GC) systems is growing at an annual rate of 14%, according to a study by Strategic Directions Intl., a Los Angeles-based consulting firm. Dominating this market are sales of GC-MS instruments, which account for more than 80% of the total. GC-FTIR and GC-AES account for the remainder.

Lower prices and environmental regulations are driving this market.



R&D Confidence Slows

The recession continued to erode managers' confidence in their ability to maintain R&D efforts, capital spending, and employment levels, according to a survey by Cahners Economics, Newton, MA.

In December, only 56% of the respondents said they would maintain or increase operations over the next few months.

IRSD BUSINESS

"In technical-intensive industries, the ability to share value-adding technical activities and transfer proprietary skills across business units can provide a competitive advantage, even in a decentralized environment," says Boyce.

"New technically complex projects, acquisitions, or alliances will be more attractive if they draw on existing core competencies or contribute to building new ones," he says.

Advancing the state of the art is inherently risky, with the result that products and process improvements are often late or miss the cost and performance target of users.

Boyce recommends that sharing information across business units is one way to more effectively monitor projects, core technologies, and successfully model project data. □

Fewer Engineers Graduate in U.S.

For the fifth year in a row, fewer people in the U.S. received BS degrees in engineering than in the previous year, according to a recent survey of 1991 graduates by the Washington-based American Assn. of Engineering Societies.

Since the peak year of 1986, the number of engineering graduates has declined 18.2% to 63,986 in 1991. During this same period, however, the number of engineers receiving MS degrees increased 20.5% to 27,754, and those receiving PhD degrees increased 54.1% to 5,680.

The total number of engineers has declined in all categories since 1986, except in aerospace, biomedical, and ceramic areas. The biggest category—electrical and electronic engineering—declined 19% from 24,514 BS graduates in 1986 to 19,858 in 1991.

A decline in the number of college-age students and less interest in engineering have been reported as the main reasons for these decreases. While the number of women receiving BS degrees declined from 1986 to 1991, the drop was not as rapid as the overall total, thus increasing women's share of the total. The number of minority BS graduates actually increased slightly to 15,958, thereby increasing their share to nearly 25% of the total. □

Europeans Buy More Foreign Equipment

European semiconductor manufacturers often favor foreign production equipment even when the technology is available in their home market, says Willem Maris, managing director of ASM Lithography, Veldhoven, Netherlands.

"European manufacturers suffer under a mentality of being behind the times in technology," he says. "The assumption seems to be that if they were to catch up, they should look to the U.S. or Japan for their production equipment, especially in the critical wafer fabrication area."

Maris believes that the European equipment manufacturers are gaining respect in global markets faster than they are in Europe. The EC's Strategic Programme for R&D in Information Technology (ESPRIT) is helping to support European manufacturers' development efforts. □

DOC Forecasts Modest Increase in Instruments

Shipments of laboratory instruments and apparatus will grow 4.5% in constant dollar value in 1992 to \$13.86 billion, according to the U.S. Dept. of Commerce's *U.S. Industrial Outlook—1992*.

Moderate expansion of the economy and growth in pharmaceutical, food processing, advanced materials, and biotechnology fields will continue to drive an annual 4% in real growth through 1996.

While domestic demand accounts for most of the expected growth, exports of analytical instruments will continue to provide a significant share of sales, says Maguerite Nealon, an analyst at the DOC's Office of Microelectronics and Instrumentation. However, foreign competition may dampen some of this growth in overseas markets.

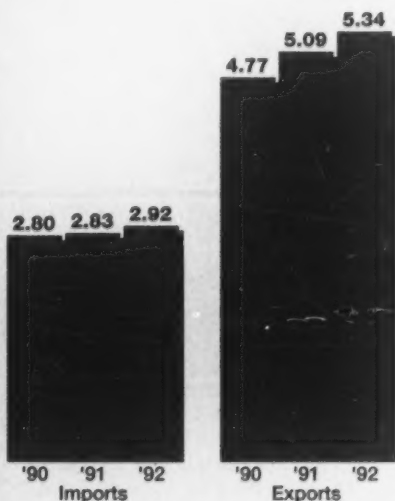
European Community countries are the largest export market for U.S. laboratory instrument manufacturers, being the destination of about a third of total exports. Canada and Mexico are the next largest export markets (17%), followed by Japan (14%), and newly industrialized countries (NICs) in East Asia (15%).

The largest sources of imports are Japan (37%), EC countries (35%), and East Asia NICs (8%).

Analytical instruments have experienced the strongest growth in the laboratory instrument and apparatus group, says Nealon. This market grew by 6% in 1991 to \$4.99 billion.

In the same category, the DOC also forecasts shipments of measuring and controlling instruments to increase by 4.5% in 1992 to \$11 billion. Here, too, exports will exceed imports by almost a two to one ratio.

Positive U.S. Trade Balance Forecast in Instruments (in billions of dollars)



Source: U.S. Dept. of Commerce

U.S. manufacturers consistently export almost twice the value of laboratory instruments as is imported.

Next Production Goal Is Total Integration

Development of integrated systems that replace today's fragmented approaches to production is the primary goal of most manufacturing managers, according to Alphonse Vitale, project director of the Automation & Productivity Institute, Stow, MA.

Vitale illustrates how different classes of advanced technologies can be combined to create new production techniques in his *Forecast of Manufacturing Technologies for the '90s*. "Manufacturing managers need to be aware of what technologies are likely to become available over the next several years," he says.

"Combining massively parallel computing methods with new vision and sensing technologies, for example, will significantly increase the number of axes that can be coordinated in future robotic systems," he says. For a copy (\$395), 508/897-1075.

R&D

Job Satisfaction Slips

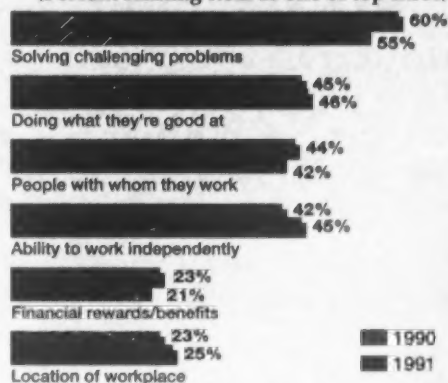


Source: 1990 and 1991 Career Satisfaction Surveys

The percentage of researchers who were very satisfied with their jobs in 1991 fell from the previous year, while the percentage of dissatisfied researchers rose. Satisfied researchers in 1991 included 75% of those in consulting, 67% in universities, 60% in industry, and 51% in government.

Researchers' Most Satisfying Job Aspects

(Percent ranking item as one of top three)



Source: 1990 and 1991 Career Satisfaction Surveys

In 1991, problem-solving was at the top of the list for researchers in consulting, industry, and government. The ability to work independently was first for university researchers.

R&D SURVEY

Satisfaction Stumbles In Tough Economy

R&D's survey data show a little drop in career satisfaction—but respondents' comments convey a lot of worry.

By John Morkes, Associate Editor,
R&D Magazine

Last year was a tough one for U.S. researchers, many of whom faced budget cuts, lost their jobs, or felt increased pressure to perform with fewer available resources.

In this difficult environment, researchers' job satisfaction slipped, according to the 1,209 scientists and engineers who responded to R&D Magazine's Career Satisfaction Survey, which was conducted in the spring of 1991.

At that time, 60% of the respondents said they were satisfied with their positions, compared with 64% in 1990 (see chart). Included in these figures were those who were "very satisfied": 18% in 1990 and only 8% in 1991.

In 1991, the survey shows, 75% of researchers in consulting were satisfied, as were 67% in universities, 60% in industry, and 51% in government.

"It's nice working for a company whose products are the best in the market and so well recognized," said one satisfied chemist.

Despite the fact that the majority of respondents were satisfied, the ma-

jority of their comments focused on the negative.

Many worried about the poor state of the economy and resulting staff reductions.

"Repeated reductions in the Defense portion of my corporation have trimmed the workforce by 25% in three years. And there's no end in sight," said an electrical engineer.

"Our company is operating under Chapter 11. Capital is tight, and employees have been laid off. It used to be a great place to work!" said a chemist.

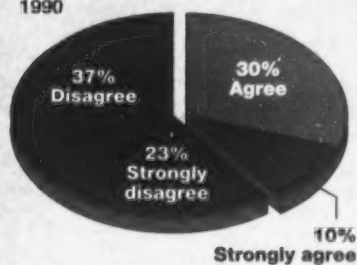
"My company's new owners have held layoffs, taken away benefits, reduced morale, and generally destroyed what was once a great corporation. We hope the economy recovers before they close the place or we all lose our jobs through layoffs. They are exploiting the lack of jobs by tightening the screws on us each day. Our managers have been reduced to rear-end-covering cowards afraid to speak their minds or fight for their employees," complained an electro-optics researcher.



Communication Breakdown

"My employer effectively communicates organizational goals to me."

1990



1991



Source: 1990 and 1991 Career Satisfaction Surveys

Workers in government (66%) complained the most about a lack of communication in 1991, followed by those in industry (56%), universities (51%), and consulting (42%). Overall, 56% saw a communication problem.

Feeling Left Out

"My employer involves the R&D department in corporate strategy."



Most researchers in government (63%) felt left out of strategy, as did 59% in industry, 53% in universities, and 52% in consulting.

Nearly a third (31%) of the respondents said they had less job security than a year before (see chart), though 15% had more job security. For 54%, the level stayed about the same.

"We were nearly axed but proved our value to the corporation. Our group's future has never been more secure," said an industrial chemist.

Researchers expressed concern about U.S. competitiveness problems, which they said have a great impact on career satisfaction. The respondents offered opinions about the problems' sources.

"American industry is extremely

wasteful of material, intellect, and energy. How do we survive?" asked an industrial chemist.

"Big Business's MBAs are destroying U.S. competitiveness," said an industrial materials researcher.

"R&D is still smothered by bureaucracy. U.S. business continues to suffer for it," said an industrial chemist.

"Between the budget deficit and corporate views of research, the U.S. will quickly become third rate," said an industrial biomedical researcher.

A majority of researchers (58%) felt that their departments were left out of corporate strategy (see chart). Many

complained of their employers' failure to back long-term projects.

"Long-term research is now defined as six months or less. R&D is getting jerked around by Marketing again," said an industrial chemist.

"The inability of the corporation to set long-term product development strategies is often frustrating," said a mechanical engineer.

Other respondents said their bosses cared more about quick profits than research.

"R&D is not valued as an asset in today's business environment; it is treated as a cost center," said a chemical engineer.

"I thought academia was full of anal-compulsive bottom-liners; industry is even worse!" said a pharmaceuticals researcher.

As in 1990, "too much bureaucracy" was the most common gripe from respondents (54%). Government employees (81%) felt the most bogged down by bureaucracy, followed by those in industry (49%), universities (46%), and consulting (31%).

For many researchers, duties such as paperwork and fund raising, which keep them from work in the lab, were worthy of complaint.

"Too much time is spent on accounting, reporting, and proposal writing. Talented people face too many barriers to spending time in the lab," said an industrial chemist.

"The main disadvantage of my job

Rewards and Opportunities

"My employer offers researchers the same rewards and opportunities to advance that it offers managers."

1990



1991

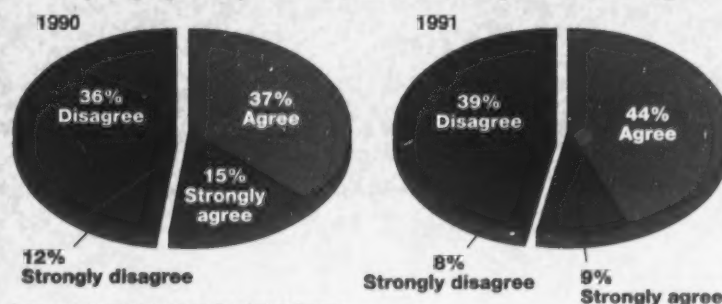


Source: 1990 and 1991 Career Satisfaction Surveys

Only 30% of the respondents said scientists and engineers received the same advancement opportunities as their organizations' managers in 1991. More women (77%) saw a difference in advancement opportunities than men (69%).

New Ideas and Independent Thinking

"My employer is open to new ideas and independent thinking."

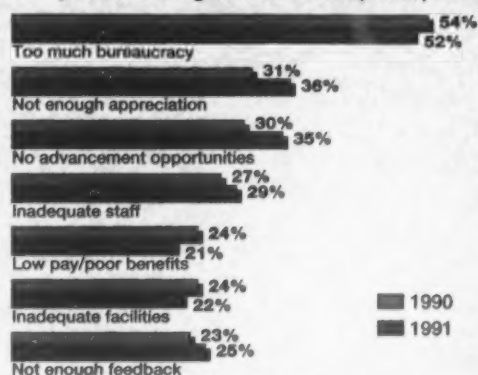


Source: 1990 and 1991 Career Satisfaction Surveys

Employers were open to new ideas in 1991, said 53% of the respondents. University researchers (65%) gave their employers high marks, followed by those in consulting (64%), industry (52%), and government (45%). Government employers received the lowest marks from 14% of their workers.

Researchers' Least Satisfying Job Aspects

(Percent ranking item as one of top three)



Source: 1990 and 1991 Career Satisfaction Surveys

In 1991, government scientists and engineers (81%) felt the most bogged down by bureaucracy, followed by those in industry (49%), universities (46%), and consulting (31%).

"'Total disgust' characterizes my opinion of my employer. Know anyone who needs a chemist?" said one researcher.

is having to beg, scrounge, and fight for funds. There is a constant battle for money. That is demoralizing and takes more time than the research," said a government ecologist.

"Not enough appreciation," cited by 36% of all respondents, was the second most common complaint. Industry researchers (38%) led the pack, followed by government (33%), uni-

versities (32%), and consulting (31%).

"No advancement opportunities" was the third least satisfying job aspect for all researchers (35%). It was cited by 37% in industry, 31% in government, 29% in consulting, and 26% in universities.

"Management has you by the short hairs, knowing there are few jobs out there these days. It makes advancement difficult," said an industrial mechanical engineer.

Overall, researchers' top three most satisfying job aspects were "solving challenging problems" (cited by 55%), "doing what I'm good at" (46%), and "the ability to work independently" (45%).

"Solving challenging problems" was the aspect cited most by researchers in consulting (74%), industry (56%), and government (49%). For 66% of university researchers, "the ability to work independently" was first.

Some respondents said that freedom was one of their most satisfying job aspects.

"Working in a nonprofit environment with the freedom to do what is needed is heaven compared to bottom-line corporations," said an industrial engineer who develops products for the blind.

Managers received much criticism from respondents. One problem area was communication: 56% of the respondents said their employers did

not effectively communicate organizational goals (see chart).

"Communication of company goals, especially long-term R&D goals, is poor. The corporate hierarchy is too distinct, inhibiting communication between levels," said an industrial mechanical engineer who serves as a project director.

Other criticisms of management were less specific.

"Managers have little common sense," said a government computers researcher.

"There are plenty of managers, but no leaders," said a government electrical engineer.

For some who were less than very satisfied with their careers, management was to blame.

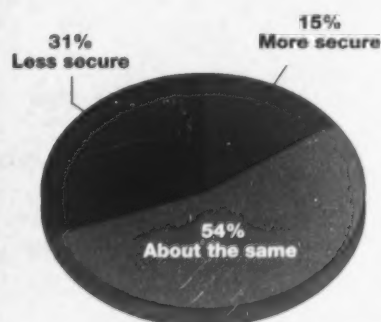
"'Total disgust' characterizes my opinion of my present employer. Know anyone who needs a chemist?" said one researcher.

Other researchers were more philosophical about career satisfaction.

"I reached my lifetime goal, yet I am not satisfied," said a chemical engineer. "It may be the nature of scientists never to be satisfied." R&D

How Researchers Rate Job Security

(Compared with previous year)



In consulting, 21% of the researchers felt they had more job security, compared with 15% in both industry and universities, and 11% in government.

READER RESPONSE PANEL

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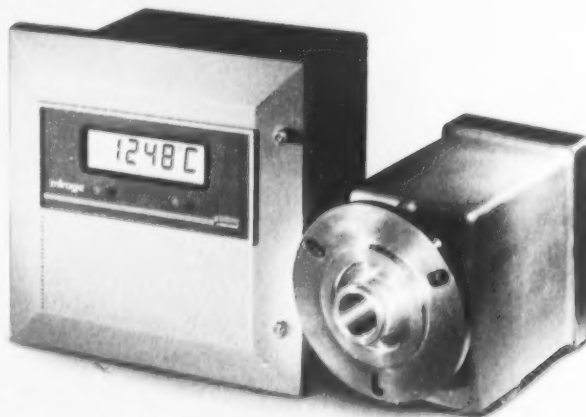
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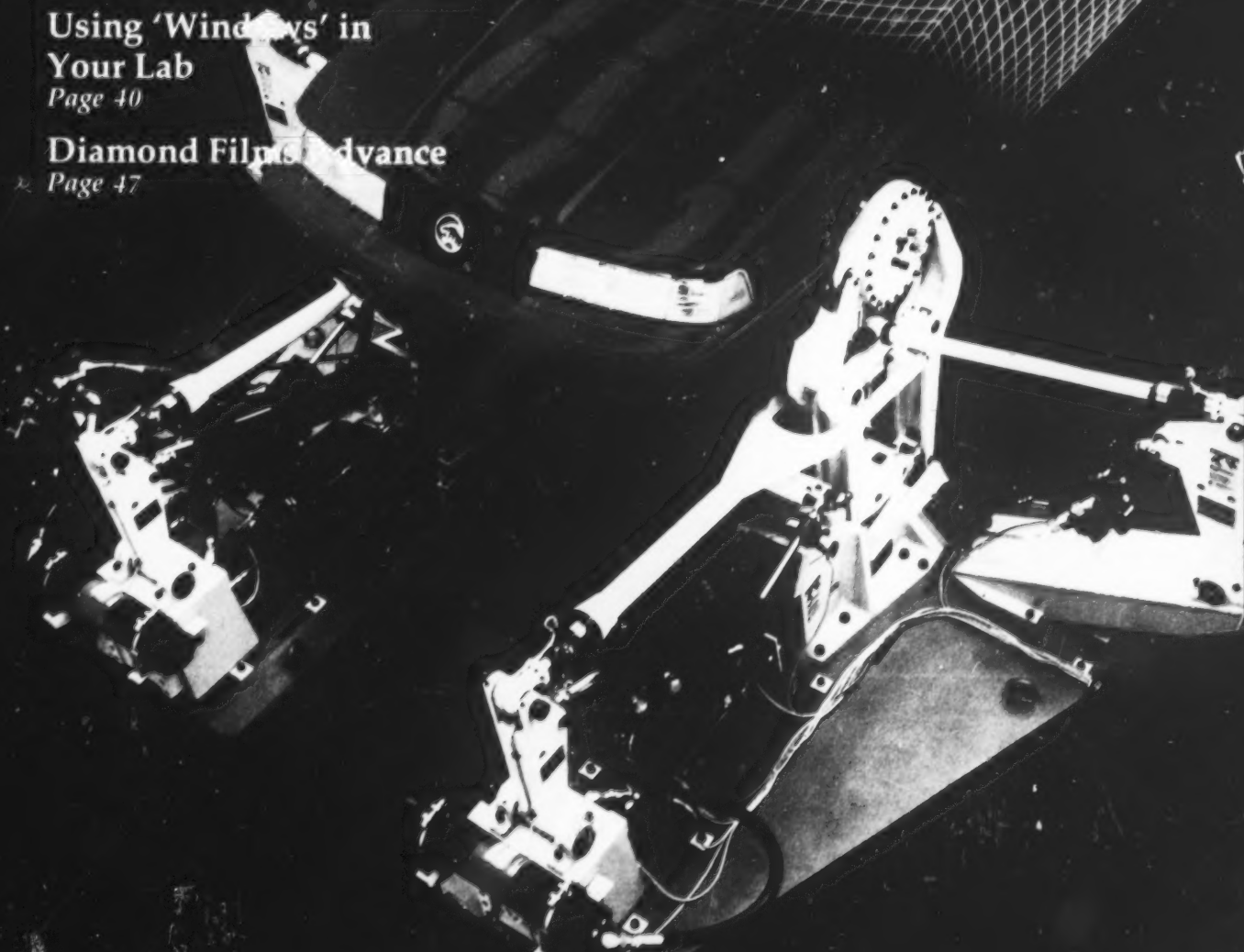
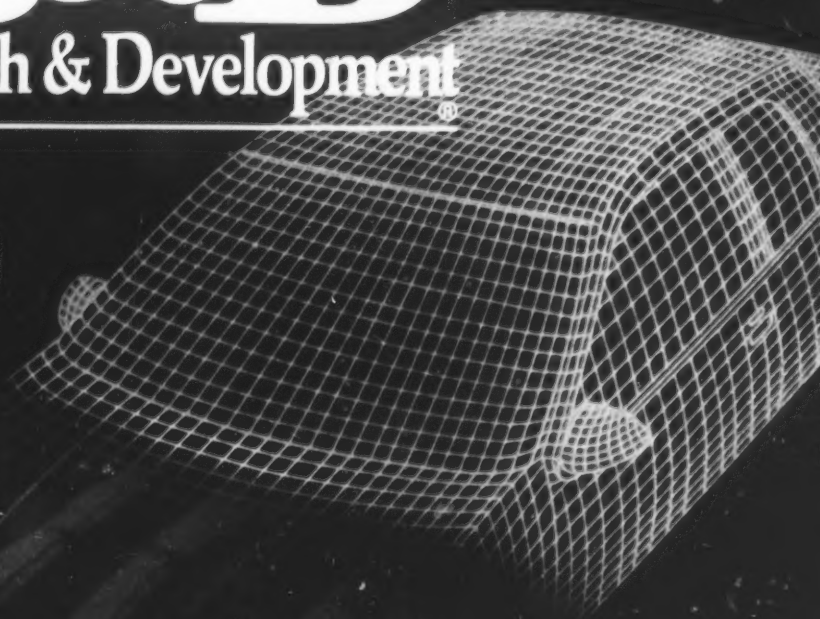
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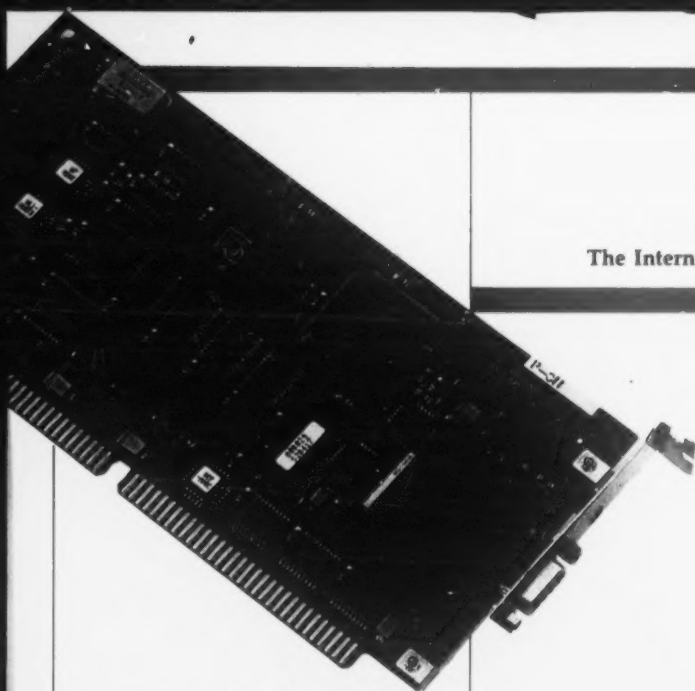
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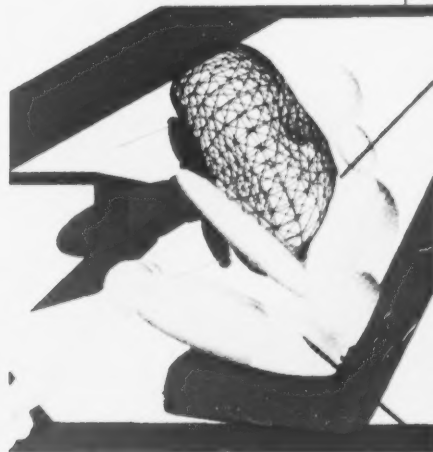
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ABOUT THE COVER Spindle-mounted laboratory road simulators are being combined with computer models to accelerate the development of new automotive designs. *Original lab picture courtesy of Ford Motor Co.*

R&D BUSINESS

Foreign Investment in U.S. Companies Slows Except in High Tech Areas

Since peaking in 1989, foreign direct investment in U.S. companies has dropped steadily over the past two years, according to recent studies. Total foreign direct investment by all countries was nearly \$60 billion in 1989, according to researchers at the Institute for International Economics, Washington, DC. This was halved in 1990 to \$30 billion and halved again in 1991 to \$15 billion.

After steadily increasing their in-

vestments over the past decade, even Japanese investors have cut back their spending from a record \$14 billion in 1989 to \$11.9 billion in 1990, and only \$3.8 billion in 1991, according to a study by the Japan M&A Reporter published by Ulmer Brothers, a New York investment bank.

Foreign investments in high-technology U.S. firms were the exception to these trends, increasing more than 30% in 1991, according to a study by the Economic Strategy Institute (ESI), Washington, DC. Japan was the largest investor in this area, accounting for more than 67% of the 536 high-technology investments reported by ESI from October 1988 to October 1991.

The largest investment increases in the high-technology area were in chemicals (a 68% increase from May to October 1991 with 21 new investments), electronics (a 41% increase with 14 new investments), telecommunications (up 34% with 15 new investments), and computers (up 27% with 28 new investments). The computer area garnered the largest number of investments with 133 of the 536 total.

More than 41% of Japan's total foreign direct investment was in U.S. companies

in 1990, according to Japan's Ministry of Finance. Japan's slowdown in overall U.S. corporate investments is attributed by analysts to several causes: the decline in the Tokyo stock market and the resultant lower availability of capital, a shift to more European investments, a preference to build new plants in the U.S. rather than invest in existing plants, disappointment with the results of earlier investments, and a desire to keep a "low-profile" to avoid political backlash.

—Tim Studt

Computer Production Dips to 15-Year Low

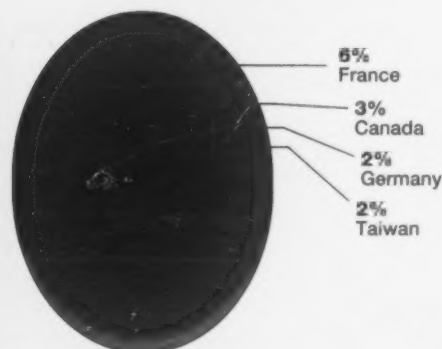
U.S. production of computer and office equipment increased a scant 3.4% in 1991, the smallest annual increase since the 10% decline registered in 1975, according to Cahners Economics (CE), Newton, MA.

Computer production surged in the final months of 1991; however, the gains were small compared to previous years' increases.

Even Japan's computer industry is sliding into its first recession, according to a forecast by the Nihon Keizai Shimbun, publisher of *The Nikkei Weekly*. The combined pretax profits of Japan's five major computer makers—Hitachi, Toshiba, Mitsubishi Electric, NEC, and Fujitsu—is forecast to drop 22% for the fiscal year ending in March 1992.

The downsizing of computer systems, from mainframes to desktop PCs and workstations, is one reason for the current decline. "Computers

Who's Buying U.S. High Tech Companies?
Share of 536 acquisitions from October 1988 to October 1991



Source: Economic Strategy Institute

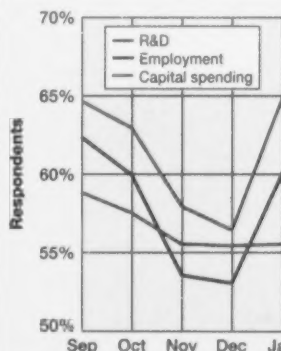
Japanese companies continue to invest in U.S. high-tech firms, such as those in composite materials, pharmaceuticals, electronics, and telecommunications.

Ease of Use Drives UV/Vis Growth



The market for ultraviolet/visible spectrophotometers is forecast to grow 8.5% annually over the next five years, according to Strategic Directions Intl., a Los Angeles-based consulting firm.

Scanning instruments make up the largest segment of this market. Ease of use and broad applicability make UV/Vis instruments a necessary part of most laboratories for a quantitative analysis.



R&D Confidence Up

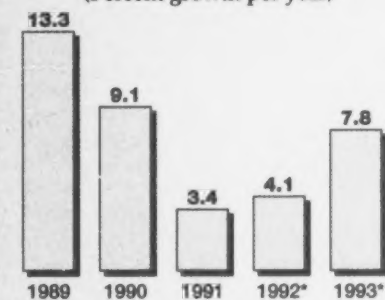
The new year brought in a brighter outlook in corporate executives' ability to maintain their business efforts, according to a survey by Cahners Economics (CE), Newton, MA.

More than 64% of the 400 companies interviewed in CE's January survey said their R&D would remain stable or increase over the next few months.

R&D BUSINESS

are being compared to household appliances, and industry profits will deteriorate further," says Noboru Makino, chairman of the Mitsubishi Research Institute, Tokyo. □

Computer Production Growth Hits 15-Year Low (Percent growth per year)



*estimated

Source: U.S. Federal Reserve Board

After experiencing its lowest growth rate in 15 years in 1991, computer production is forecast by Cahners Economics to slowly increase over the next two years.

High-Tech Firms Hire Most Engineers

U.S. manufacturing industries employed more than 1.7 million scientists, engineers, and technicians (SET) in 1989, according to the National Science Foundation, Washington, DC.

Nearly 82% of these personnel were employed in only six high-technology industries—instruments, chemicals, transportation, electrical machinery, nonelectrical machinery, and refined petroleum products.

The SET figures consisted of 192,000 scientists, 804,000 engineers, 586,000 technicians, and 144,000 managers. SET personnel in manufacturing R&D areas comprised 191,000 of the total. For more information, call 202/634-4284. □

NIH Sponsors Tech Transfer Program

Have a problem with squirrels eating the birdseed before the birds can get to it? Solutions to this and other problems are available through a U.S. Public Health Service (PHS) technology transfer program administered by the National Institutes of Health, Bethesda, MD, for all PHS agencies.

Information concerning these programs is contained in the 1991 *Technology Transfer Directory*. For information, call 301/496-0750.

By the way, NIH researchers solved the birdseed problem by coating birdseed with capsaicin-like compounds. Capsaicin, the pungent ingredient in chili peppers, repels mammals, but is readily consumed by birds who lack hot-taste receptors. □

Plan Now For Next Economic Upturn

Harry W. Matthews Jr., a consultant with Arthur D. Little Inc., Cambridge, MA, encourages companies to establish several programs to improve their capabilities for the next upturn. He says that during the current recession companies should:

- Prune dead products
- Close unproductive plants
- Cut unnecessary fixed costs
- Activate allies
- Advertise in niche markets
- Develop high-performance teams
- Create new labor arrangements
- Streamline the work process
- Continue R&D
- Improve response time.

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R&D SOFTWARE

Support Problem Solver

Mahogany HelpDesk version 2.0 is designed to improve the quality and speed of problem resolution in customer support, technical support, and helpdesk environments.

Emerald Intelligence Circle 347

Mass Spec Library Search

Version 2.2 is an enhancement of BenchTop/PBM, a PC software product for mass spec library search. The system uses the easy-to-use Microsoft Windows environment to combine PBM library search algorithms with the Wiley Registry of Mass Spectral Data, 5th Edition. Version 2.2 includes expanded background subtraction capabilities, a new mass chromatogram display, and new features for editing and averaging scans.

Palisade Corp. Circle 344

Intelligent X-Ray Analysis

IMIX XD provides the analyst complete control over spectral display, including presentation of multiple spec-

tra for comparison on split-screen display to highlight detail. Several separate display windows can be used, each having up to 16 spectra. XD also features Energy Windows, providing quick access to elemental x-ray line data for peak integration, digital "dot maps," and elemental line profiles.

Princeton Gamma-Tech Circle 345

Driver for High-Speed Data Acquisition Boards

The driver program offers several new trigger commands, improved memory support, and more efficient memory usage. The combination of this new driver and the company's Flash-12 and WorkMate boards performs many functions that have come into demand for high-speed data acquisition, up to 1 MHz.

Strawberry Tree Inc. Circle 273

Calculate 2-D IR Correlation Spectra

The company created 2DIR to run under Lab Calc, its powerful post-processing software. The program simplifies the analysis of time-resolved spectroscopic responses of a sample to sinusoidal perturbations.

Galactic Industries Corp. Circle 346

CIRCULATION

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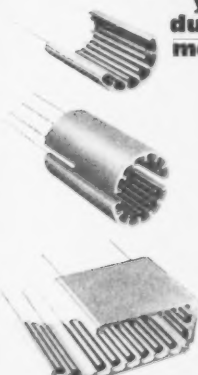
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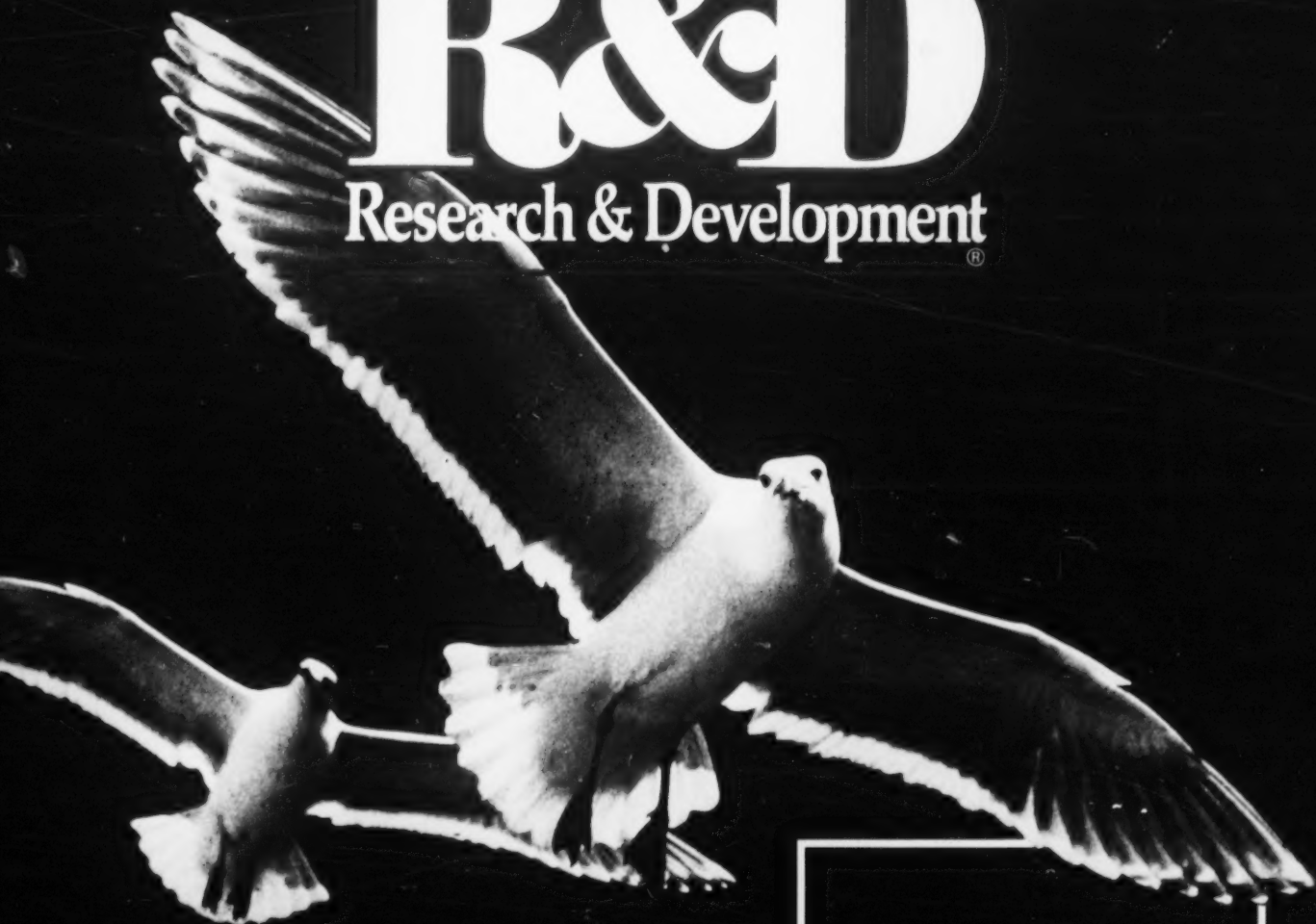
April 1992

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R&D

Research & Development[®]



SMART MATERIALS

Technology Imitating Nature

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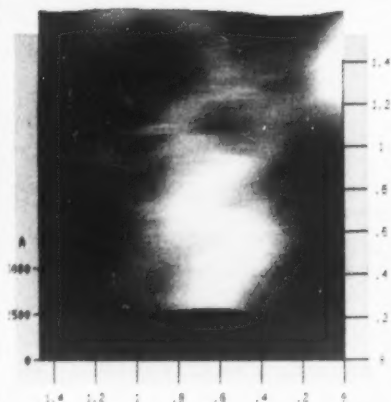
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ABOUT THE COVER Integral shape memory alloys allow the synthetic wing to deform without the need for complex mechanisms. See article page 54. Photo: Virginia Polytechnic Institute.

R&D

The International Magazine of Research and Development

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Spotlight on Danish Technology 33

A special section featuring advances in accelerator systems, biotechnology, chemistry, computer modeling, electronics, environmental research, lab equipment, materials research, pharmaceuticals, telecommunications, and more.

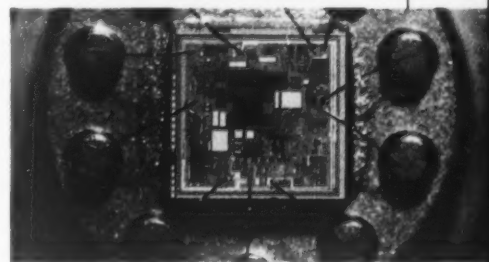


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Smart Materials: Creating Systems That React 54

By combining new electroactive materials, researchers are developing integrated systems that adjust to a changing environment.



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INSTRUMENTATION

Thermal Analyzers—They're Not Just for Plastics 64

High-tech automation, microprocessors, and software controllers are expanding the uses for thermal analysis instruments.

MICROSCOPY

Imaging With Inelastic Electrons Gives TEM New Flexibility 72

An electron-energy prism lets biologists and materials scientists produce 'compositional maps' of cells, metals, and polymers.

ENVIRONMENTAL RESEARCH

Carcinogen Research—From Statistics to Hard Science 78

A field called molecular epidemiology goes beyond correlation studies to measure cancer-causing damage to cellular DNA by pollutants.

VACUUM TECHNOLOGY

Silicon MBE Research Races Toward Production 87

Though problems remain, the effort to produce silicon-based devices using molecular beam epitaxy is progressing rapidly.

R&D BUSINESS

Record Number Of Patents Issued

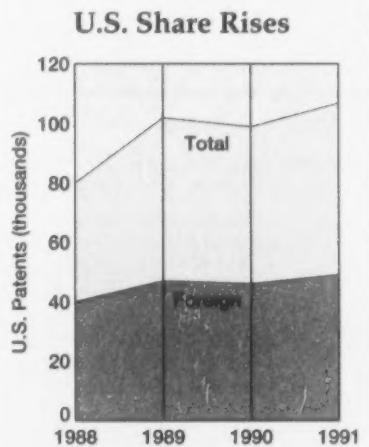
The number of patents issued by the U.S. Patent and Trade Office, Washington, DC, reached record levels in 1991, when 106,882 were issued, according to a recent survey by MicroPatent, a New Haven, CT-based publisher of patent information. This is a 7.1% increase over the 99,275 patents issued in 1990.

U.S. inventors continued their comeback in 1991, increasing their share to 54.1%, up from 53.4% in 1990. This is the third straight year U.S. inventors increased their share, after losing share to foreign inventors from 1977 to 1988.

Japanese inventors also continued their share improvement of U.S. patents, increasing from a 20.9% share in 1990 to a 21.0% share in 1991. The 22,403 patents that Japanese firms received in 1991 is the most that any foreign country received in one year and nearly equals the annual amount that all foreign countries received in the late 1970s.

The top 10 list of corporations receiving the most patents was mainly a repeat of previous years. There was a slight shuffling in the order of the top five firms, which continued to be dominated by Japanese industrial conglomerates. Motorola broke into the top 10, edging out Siemens, holder of last year's 10th place. Motorola increased its number of patents by almost 50% in 1991 from 427 in 1990.

For more information, call 203/786-5500. ☐



Japanese Hold Top Patents

Hitachi	.1,188
Toshiba	.1,165
Mitsubishi	.965
Canon Kabushiki	.918
Eastman Kodak	.878
General Electric	.867
Fuji Photo	.766
U.S. Philips	.692
IBM	.688
Motorola	.640

Source: MicroPatent

U.S. patents awarded in 1991 increased 7.1% to a record level of 106,882, with five Japanese firms combining for more than 5,000 patents alone.

Loss of Tax Breaks Hurt U.S. R&D

The U.S. Tax Reform Act of 1986 may have been responsible for a reduction of between \$1.4 billion and \$2.2 billion in annual R&D spending in the U.S. by 1989, according to a recent study by James R. Hines Jr., a researcher at Harvard Univ., Cambridge, MA.

Prior to 1986, U.S. multinational firms were allowed to deduct all of their domestic R&D expenses against their U.S. income for tax purposes. After 1986, some firms could take only a partial deduction, while other firms were allowed the full allowance.

Hines found that the price-elasticity of demand for R&D allowed more price sensitivity than is typically assumed.

By the way, the tax change resulted in \$1.2 billion in additional revenue.

For a copy of the report, ask for Working Paper No. 3930 (\$5) from the National Bureau of Economic Research Inc., 617/868-3900. ☐

Aero Firms' Trade Up, R&D Down

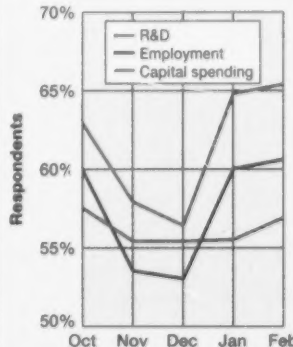
For the sixth consecutive year, the U.S. aerospace industry set a new record in 1990 by exporting \$39.1 billion, a gain of almost 22% over the \$32.1 billion record set in 1989. This is in contrast to its long-term efforts, as industry-funded R&D dropped by more than \$117 million in 1991 to \$6.8 billion, according to a new report

SFC Continues in Growth Mode



The market for supercritical fluid chromatography (SFC) systems is forecast to grow nearly 20% annually to \$36 million in 1996, according to a study by Strategic Directions Intl., a Los Angeles-based consulting firm.

SFC is still considered a fledgling chromatography method, having been commercialized in 1982. It competes against established HPLC and GC methods.



Confidence Still Up

Corporate executives' confidence in their R&D efforts reached its highest level in nine months, according to a monthly survey by Cahners Economics, Newton, MA.

More than 66% of the survey respondents indicated they would maintain or improve their R&D capabilities over the next few months.

R&D BUSINESS

by the Aerospace Industries Assn. of America Inc., Washington, DC.

Government-funded R&D for the aerospace industry is increasing, for the present, with many programs still seeing increases in the proposed FY93 budgets. The 30% drop in new orders from the U.S. government in 1990 was partly responsible for the drop in industrial R&D. U.S. Dept. of Defense appropriations for R&D are esti-

mated to grow by more than 15% in 1992 to \$39.9 billion.

For a copy of the report, *Aerospace Facts & Figures, 1991/92* (\$25), call 202/371-8561. □

Biotech Bright Spot In U.S. Economy

"Over the next three years, biotech revenues may exceed \$40 billion, and the number of professionals will quadruple," says Cynthia Feldman, chair of the bioscience and technology group of Coopers & Lybrand, Boston.

"CEOs in the southwest U.S. have the most aggressive projections," she adds. "By 1995, they expect more than 700% growth in revenues."

Public equity financing of biotech companies in 1991 exceeded \$3 billion, their best year yet. Government biotech support is surprisingly strong, with recent proposals to reduce some

Nearly half of all biotech companies have \$3 million or less in annual revenues.

testing requirements.

Two recent reports cover biotech subjects—*Leadership in Biotechnology*, covering organizational and compensation issues, and *Public Equity Financing in the Biotechnology Industry*. For copies, write to Coopers & Lybrand, Attn: Publications Dept., 1251 Avenue of the Americas, New York, NY 10020. □

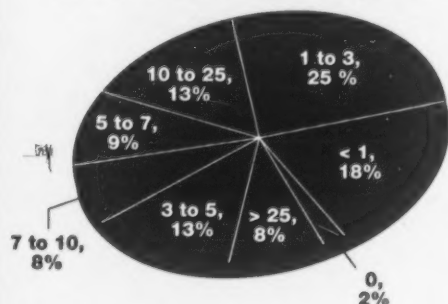
NIST Answers ISO 9000 Questions

Which quality management program is the right one for the different ISO 9000 standards? Will the ISO standards help you win a Malcolm Baldrige quality award? Do you even know all the ISO terminology?

These questions are answered in a report from the U.S. National Institute of Standards and Technology: *Questions and Answers on Quality, The ISO 9000 Standard Series, Quality System Registration, and Related Issues*.

ISO standards are already mandated by many governmental bodies in the U.S. and abroad. For a copy (NISTIR 4721) send a self-addressed label to: Standards Code and Information, A629 Administration Bldg., NIST, Gaithersburg, MD. 20899 R&D

Biotech Firms Start Small
Projected 1992 sales (in millions of dollars)



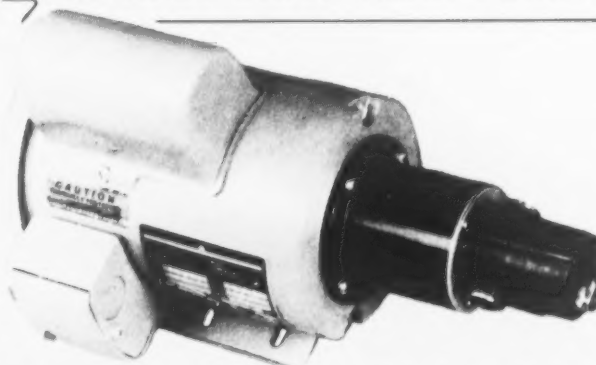
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Infometrics

Circle 342

HP MOTIF Version Of Point & Click

The HP MOTIF version of the company's PV-WAVE Point & Click runs on the HP/Apollo 9000 Series 700 workstation. PV-WAVE Command Language—the sister product of Point & Click—runs on HP/Apollo 9000 Series 300, 400, and 700 platforms.

Precision Visuals

Circle 340

Process Plant Simulations

The SIMUCEL package provides a powerful way of dynamically simulating continuous and discrete activities of process plants in industries such as chemicals and chemical-related products, lubricants, paint, rubber, and food processing. The program helps in operating today's plants in an increasingly competitive market.

Cellier Corp.

Circle 343

Data Acquisition Demo

The demo of EASYEST LX shows the capabilities of this PC-based, icon-driven data acquisition, graphics, and analysis package that merges deluxe setup and testing tools with a novel, no-hassle method of application development.

Keithley Asyst

Circle 347

Development Demo

A free demo program gives a comprehensive overview of the LabWindows 2.0 software development system for programmers using C and BASIC for data acquisition and instrument control applications. The demo gives a guided tour of the software.

National Instruments

Circle 344

Stop Smoking!

The suggestion software uses the principle of self-hypnosis. Its database of affirmations and self-analysis questions make each 5-min session a new experience.

David's Designs

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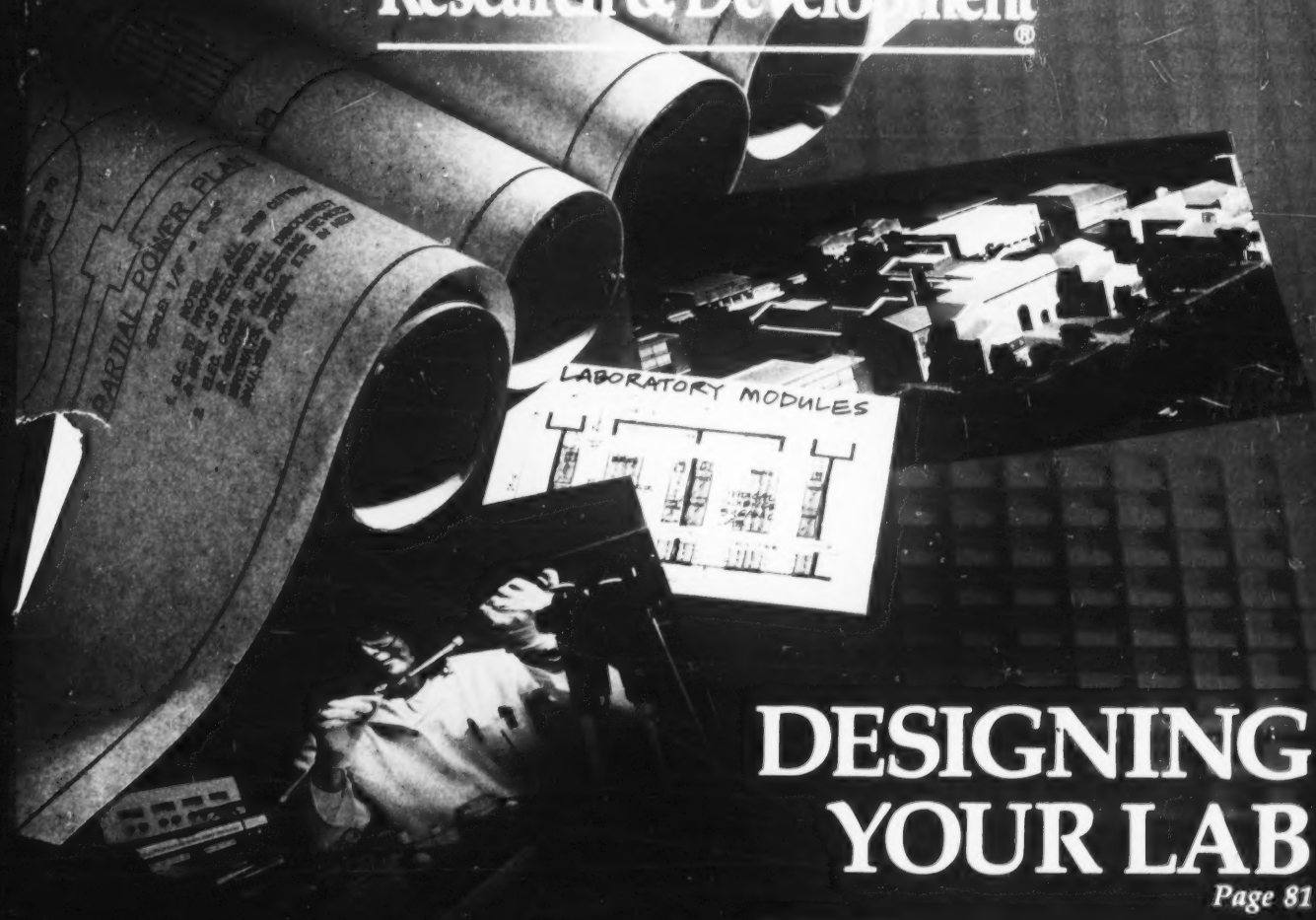
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A Cahners Publication

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DESIGNING YOUR LAB

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Laboratory of the Year—
Rice's Rising Star

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Exclusive White Paper:
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ABOUT THE COVER *R&D Magazine* presents a special feature section devoted to designing and locating your new research facility. See articles beginning on page 65.

R&D

The International Magazine of Research and Development

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A reunified Germany demonstrates the strength of its technology in aerospace, automotive design, environmental research, lasers, optics, instrumentation, medical devices, vacuum technology, and semiconductors. Plus an interview with the Minister of Research & Technology.

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Rice's George R. Brown Hall is named *R&D's* Laboratory of the Year. Three other labs receive special recognition.

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Here's a selection of new products to consider when designing or updating your lab.

LASER RESEARCH

Diode Pumped Lasers Finding Commercial Applications 89

Diode pumped solid-state lasers are starting to prove themselves in materials processing and other commercial areas.

VACUUM TECHNOLOGY

Is 1992 the Year of the Mini In Cleanroom Technology? 97

Only a few years ago, robotically controlled mini-environments were a radical idea. Now, the only question is when the idea will sell.



Lab of the Year, page 72

R&D BUSINESS

Upward Trend Shown in National Labs' Ability to Transfer Technology

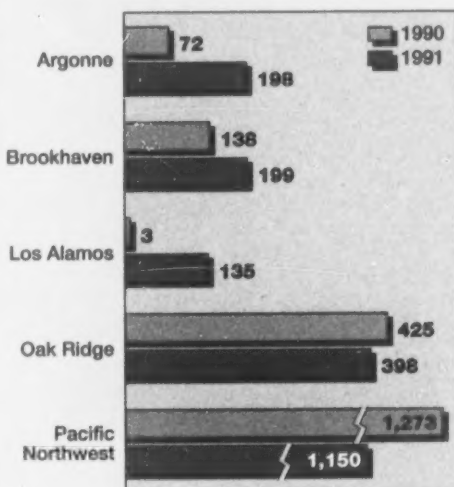
The number of new licenses and the licensing income from technology developed at U.S. Dept. of Energy national laboratories and transferred to the industrial sector are slowly increasing, according to a recent survey by *R&D Magazine*.

For five of the nine multi-program DOE laboratories for which information was available, the number of new licenses granted increased from 76 in 1990 to 82 in 1991. Licensing income increased nearly 9% from \$1.9 million in 1990 to \$2.1 million in 1991.

Royalties generally lag behind licensing activity because development and introduction into the marketplace usually take several years.

A significant amount of the current royalties went directly back to the laboratory inventors. Dependent upon the specific laboratory and the size of the royalty, inventors received from 15% to 50% of the royalties. In general, the remaining royalties were retained by the laboratory for general R&D or to support technology transfer activities, such as patent prosecution, employee awards programs, or to support cooperative research and development

DOE Licensing Income Matures (Thousands of dollars)



Source: U.S. Dept. of Energy, *R&D Magazine*

Licensing income from tech transfer programs at U.S. DOE national labs often is evenly split between the product inventors and support for further programs.

agreement (CRADA) programs.

Patenting, including foreign coverage, also has increased over the past several years. Pacific Northwest Labs, Richland, WA, for example, has increased its annual U.S. patent average from 10 to 25 applications per year.

"The DOE encourages transferring

these achievements to universities and to industry," says William Harper, director of the Office of Energy Research, Washington, DC.

The 176-page *Technology '91* summarizes the technologies available for transfer from DOE labs. For a copy, call 615/576-8401. —Tim Studt

Social Concerns Spur Materials Choices

Social concerns have much more importance in the selection and development of new materials than they had in the past, according to a recent U.S. Bureau of Mines report on advanced materials, *The New Materials Society, Volume 3—Materials Shifts in the New Society*.

Issues such as how much energy is needed to produce a new material, how the material or its production process affects the environment, if the material is renewable, or if it is recyclable are being given the same weight as conventional selection criteria, such as cost, availability, performance, and customer preference.

As a result, the people involved in selecting and approving new materials have changed, according to the report. Design engineers used to be left alone to make most materials selections, but now middle and upper management are routinely involved in the materials selection process to ensure compliance with all environmental and nontechnical issues.

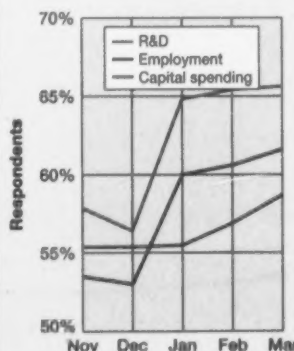
For a copy of the report (\$7) or volumes one (\$8.50) or two (\$15), call 202/512-2457. □

Computers Drive LIMS Growth



Technological advances, resulting in the increased flexibility and cost effectiveness of computer systems, are driving 11% annual growth in laboratory information management systems (LIMS), according to Strategic Directions Intl., a Los Angeles-based consulting firm.

Once dominated by mini- and mainframe computers, PC-based systems now account for about 35% of LIMS sales.



R&D Outlook Up

Corporate executives' confidence in their ability to maintain or increase their R&D efforts over the next several months reached its highest level in March from readings taken over the past 10 months by Newton, MA-based Cahners Economics.

This was the third straight increase, following the late-1991 confidence slump.



YOUR

AN R&D EXCLUSIVE MANAGEMENT REPORT

ettling on a decision to build a new R&D facility is an involved process for any organization. The timing of such a move is crucial, as are an array of factors that impact on site location. *R&D Magazine* recently asked 1,000 top-level R&D executives to specify the issues that you must address if a new facility is to succeed. The U.S. and Canadian research executives—all readers of *R&D Magazine*—identified 25 top considerations and ranked them in their order of importance. These industry executives speak from experience. Three out of four have been involved with new laboratory construction, and nearly 40% plan to build a new facility or expand their existing laboratory within the next two years. The survey, believed to be the first of its kind, revealed:

The most important factor in deciding *whether* to build an R&D facility is the demand for research projects within the company.

The corporate bottom line and the financial climate generally dictate the *timing* of the move.

A host of labor issues affect site location—including the availability of a technical labor force, the local education level, housing costs, and even the local work ethic.

Easy access to the European Community and other foreign markets weigh heavily in the decision to locate internationally.

'Research parks offer staff members more opportunities to exchange thoughts with colleagues in a variety of disciplines, both at work and during leisure hours.'

The demand for research projects within a company is important in focusing attention on the need for some kind of expansion effort, the responding executives indicated. However, the types of projects being proposed determine whether a present laboratory will be expanded or a new facility will be built.

Planning for a new facility must be extensive and based closely on the research activities to be conducted there, with an allowance made for growth, the respondents advised.

"Establish a planning team from the occupants who will staff the new facility. It's very important to have their input," suggests Richard Montgomery, of Unilever Research U.S., Edgewater, NJ.

"Next, determine what departments are best to have contiguous to one another. For example, should the analytical group adjoin the polymer chemistry people or the organic synthesis unit? And after you have placed the groups close to one another, you have to ask how will they expand or contract in the future, once they have been positioned. Remember, as business changes, the physical layout of the research facility may also require modification," says Montgomery.

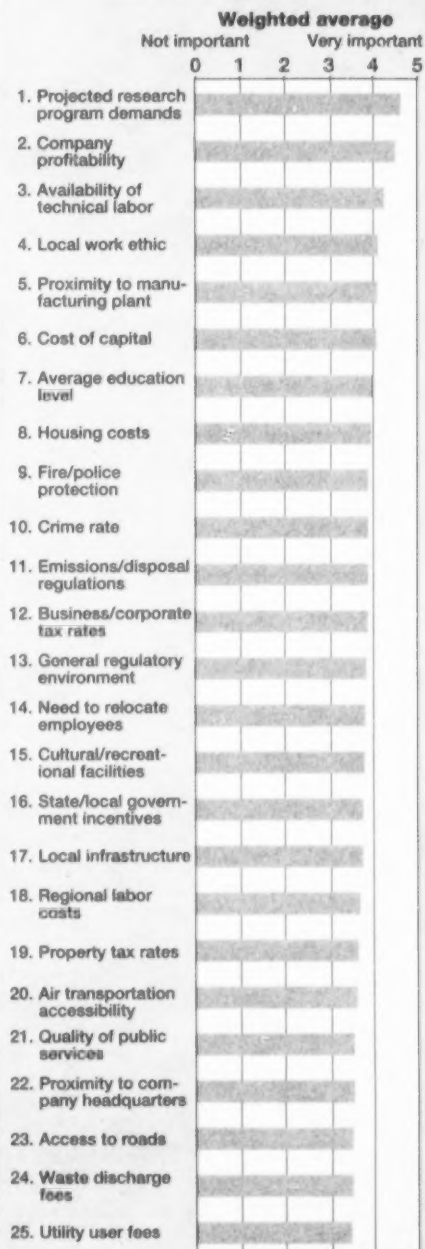
Things really don't get much easier when a facility expansion is involved. "When planning a lab expansion, you have to maintain a delicate balance," says Steven Ostertag, advanced engineering supervisor for Zexel-Gleason USA Inc., Rochester, NY, specialists in automotive drive-train designs. "On one hand, real estate is too expensive to sit idle, but conversely you need to be flexible and have floor space available for any directional changes that may occur in your research program."

Perhaps the "balance" Ostertag mentions should favor idle space somewhat because many respondents warned against making the facility too small.

"Do not underestimate the physical area needed for large equipment and test setups," cautions James Moschenross, test engineering manager at General Connectors Corp., San Fernando, CA. "Items such as environmental chambers, air compressors, and a network of air ducts require tremendous space for satisfactory operation."

"It seems that as soon as we finished

What Are the Important Factors in Choosing a New Laboratory Site?



The top 25 factors to consider when locating a research facility are ranked in order of importance by the R&D executives responding to the site selection survey.

construction, we found that the new facility just wasn't big enough," bemoans another veteran manager who received his stripes in a lab expansion project.

Several R&D executives indicated their first step in planning a new facility was to hire a consulting architectural and engineering firm, one that has experience in building research laboratories. The key is to find a firm who understands the R&D business, can provide a layout, estimate costs, and then know where to make compromises to fit the budget.

Ideally, the timing of an expansion program should be dictated by market projections for the products to be developed in the new facility.

In the real world, however, financial considerations dominate. And the most dominant of all is the company's profitability picture, the survey showed. Next comes the cost of capital, followed by the availability of financing and the economic outlook at both the national and local levels.

"Keep an eye on the return on investment" was a comment heard from many respondents.

Even with our current uncertain economic climate, nearly 40% of the respondents stated their organization is planning to build a new facility or expand their existing laboratory within the next two years—a very positive indicator of future research activity.

Of the factors affecting the selection of a site for a new R&D facility, the highest ranking were the availability of a technical labor force and the local workers' work ethic. The local educational level was also an important consideration, but scored farther down the list.

Proximity to the company's manufacturing plant ranked fifth in importance. This was stressed particularly by executives at diversified companies like MacLean-Fogg Industries, Mundelein, IL, where a multiple laboratory arrangement is used.

"We have seven manufacturing plants, each producing different products and serving different markets. As a result, we tend to be very decentralized and require a product/process development laboratory to be located at each manufacturing facility," says

George Pazdirek, MacLean-Fogg's engineering vice president.

Although 55% of the respondents indicated they had no preference in locating a new facility on a stand-alone site or in a research park, 27% did prefer a stand-alone site adjacent to either the company's manufacturing plant or corporate headquarters.

However, 18% of the R&D executives questioned said they would prefer to be located in a research park because of the unique advantages available in that environment.

"Research parks offer more opportunities for staff members to exchange thoughts with other colleagues in a variety of disciplines, both at work and during leisure hours," says one enthusiastic manager.

The sharing of resources is another benefit found in a research park. The proximity of such synergistic relationships could prove to be a hidden treasure.

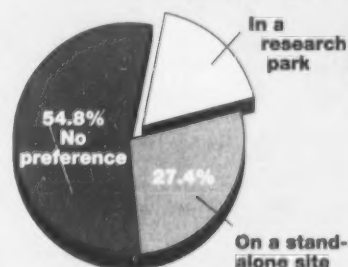
Yet some R&D managers saw dangers in all this. One felt that a separate location provides better protection for trade secrets. Another respondent stated that the stand-alone site concept helps a company focus on its identity.

Rounding out the list of major factors to consider in locating a facility were considerations such as local housing costs, the crime rate, fire and police protection, corporate tax rates, and the regulatory environment.

The need to relocate employees, local cultural and recreational opportunities, and the quality of local infrastructure also appear to be significant factors in selecting a research facility location.

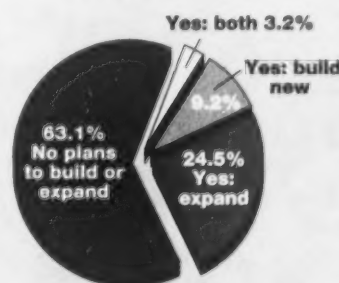
The time may come in your professional career when you will be asked to participate in a laboratory construction project. If you are like our R&D professionals, you will find it to be a worthwhile learning experience.

Where Would You Locate a New Facility?



The environment of a research facility is just as important as its address. Research parks can offer unique advantages.

Plan To Build or Expand Within 2 Years?



Nearly 40% of the respondents are planning new laboratory construction or expansion—a positive indicator of future research activity.

Foreign Research Centers Make Sense

A foreign R&D facility lets you tailor your product to the marketplace in which it will be sold.

Thirty percent of the respondents to our survey noted that their companies currently operate a research facility in a foreign country.

Our survey found that the most important reason for doing so revolves around the opportunity to better serve the European Community and the other international markets.

"You have to make your R&D relevant to the marketplace," says Zexel-Gleason's Ostertag.

"If you want to be in touch with your customers, you need to be where your customers are," continues Ostertag. "And this means either you transport your R&D people around the world continually, or you set up small R&D spin-off centers in each country."

Jonathan Yuen, director of Singapore's Economic Development Board, New York, also stressed the importance

of tailoring a company's product to fit the marketplace in anticipation of selling that product in the foreign market.

"This might involve minor design alterations, or it may require developing an entirely new product from scratch, depending upon the industry," says Yuen.

Having a direct link to international technology also scored very high as a reason to locate internationally.

"Synergy is an excellent benefit obtained from locating a research facility in a foreign country," says John Falk, an independent consultant in Northbrook, IL. "You frequently get a different perspective from researchers who were born and educated outside the U.S., offering different points of view to similar problems."

"The marketplace also can provide a different perspective because of the cultural differences," says

Falk. "However, making use of this requires not only the desire to do so on the part of technical management, but upper management's commitment as well."

The availability of a country's skilled technical labor force was another major attraction.

"In the R&D business, the three prime considerations are people, people, and people," says Martin Togneri, North American director of Locate In Scotland, Stamford, CT.

"The quality of the people, the skills they demonstrate through their research and development activities, and their track record of innovation all indicate the level of their technical ability," states Togneri. "These are the factors companies should consider very carefully when searching for offshore R&D locations."

U.S. companies are recognizing the need for offshore research centers. "With international sales approaching 50% of total revenue, we may eventually consider establishing an R&D facility in a foreign country," says Leonard Cordone, director of advanced engineering and development at Bausch & Lomb Inc., Rochester, NY.

"Our business projections indicate that major growth opportunities lie outside our domestic markets, and it makes sense for us to be located overseas to support the further development of our product lines, especially in a regulated industry such as ours," says Cordone.

Many countries have established a variety of research and industry-oriented parks to encourage R&D facilities to locate on their soil.

"Foreign corporations have been quick to take advantage of France's high technology environment," says Fanny Hostie, Invest in France Agency, New York. "Many companies have already set up R&D centers within the 35 research parks located throughout our country."

In today's global economy, the future of foreign R&D centers looks extremely bright, especially with so many countries eager to wave their lantern.

—Prepared by Howard J. Goldner,
Associate Editor

What's Important in a Foreign Location?



Access to foreign markets and technology received high marks by R&D executives. Meeting the needs of foreign clients is also considered important.

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The Area Detector Strategy Organizer (ASTRO) provides superior single-crystal x-ray diffraction data for all crystal settings and space groups. The ASTRO strategy package is an interactive graphics program that helps users determine which series of scans will most efficiently collect the x-ray data required for structure determination. *Siemens Analytical X-Ray Instruments* **Circle 348**

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The PC-551 UV-Vis software allows the company's RF-551 fluorescence HPLC monitor to double duty as a scanning fluorometer. PC-551 uses the Microsoft Windows graphical interface and provides three acquisition modes (spectrum, quantitative, and time course) to support a wide variety of fluorescence applications. Graphic displays and tool buttons help the researcher find peaks and valleys. *Shimadzu* **Circle 340**

CIRCULATION

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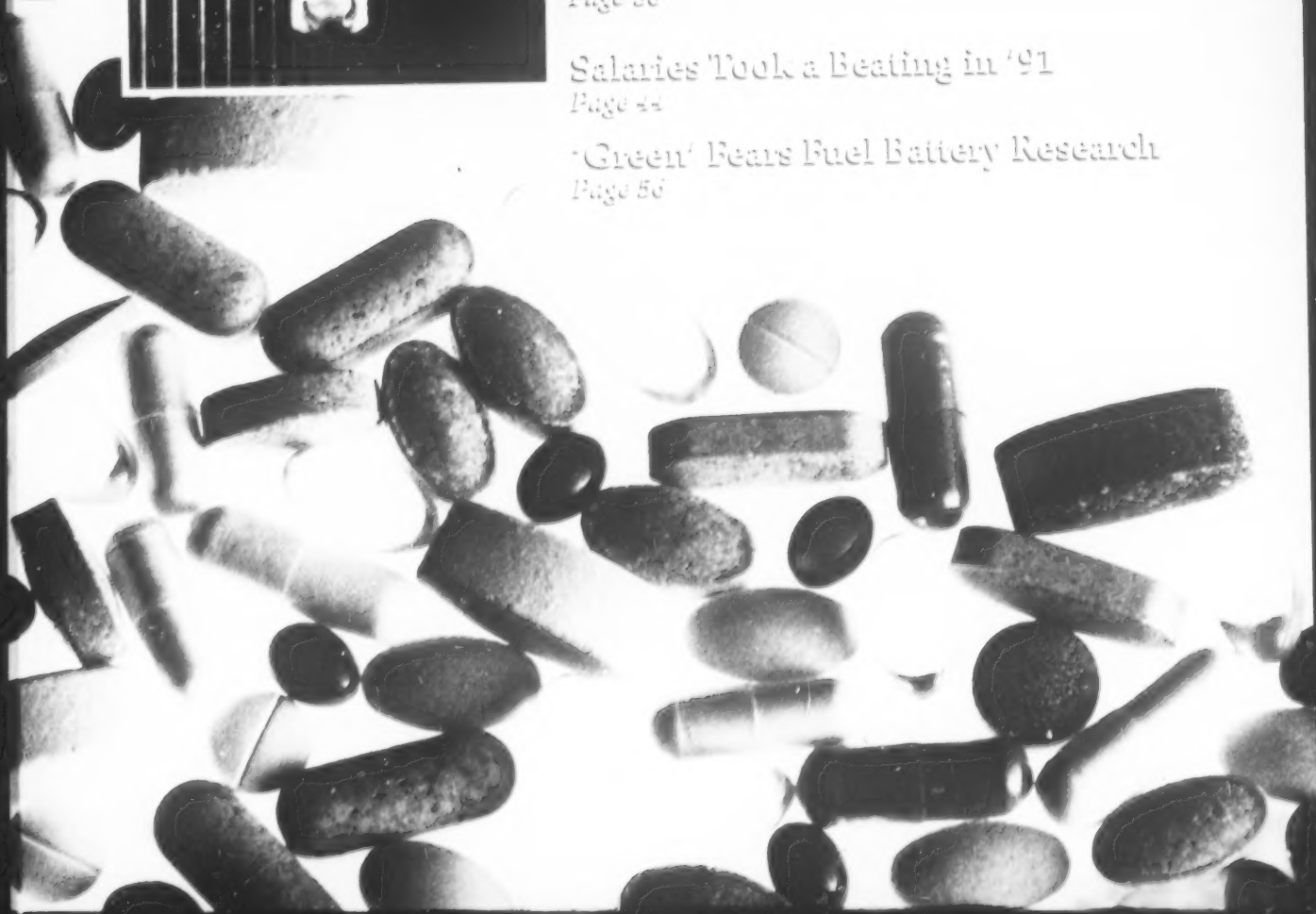


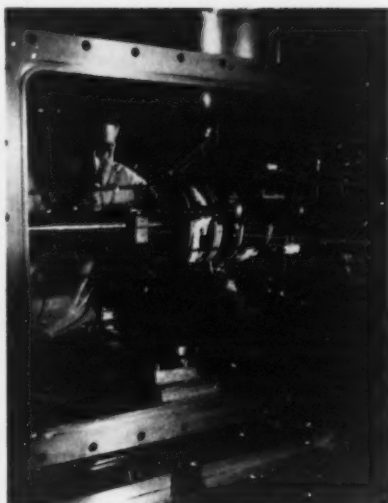
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The International Magazine of Research and Development

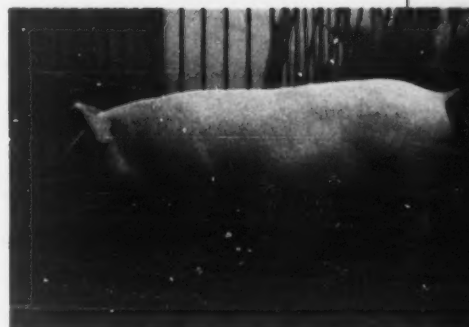
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Genetic engineers have created 'pharm' animals that produce therapeutically important proteins—in bulk.



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Anodic vacuum arc deposition applies fine-grained metallic films fast and could help dethrone electroplating as the dominant technology.

ABOUT THE COVER "Pharm" cows sired by Herman, the first transgenic dairy calf, could become a plentiful source for human lactoferrin. See article, page 36. Photo: GenPharm International.

R&D BUSINESS

Flash Chips Become Enabling Technology

Rapid market growth for flash memory devices is expected following both price reductions and data storage increases by the Memory Components Div. of Intel, Folsom, CA. Intel is the market leader in flash devices with about 85% of the world market.

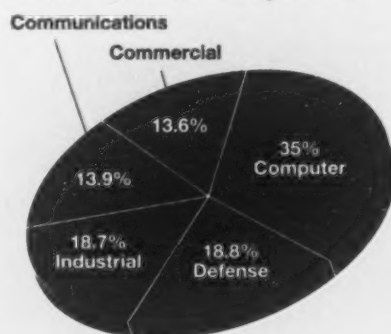
Flash chips are solid-state computer memory devices that are simpler in construction than current DRAM chips used as volatile computer memory. Flash chips, however, are non-volatile devices that store data indefinitely, without a battery backup, yet can be easily erased and reprogrammed. Intel recently announced a \$29.90 price for an 8-Mbit flash chip, making it comparable to current DRAM prices in costs/Mbit.

The flash memory price reduction, however, means that they still are about six times as expensive as comparable hard disk systems. Disk systems will be around for a while longer, since disk researchers are continuing to increase their capacity with development of new materials and thin-film processing systems.

Compared to disk memory systems, flash chips are more rugged, smaller, and use less power. These characteristics will drive flash chip use in embedded applications, such as disk controllers, laser printers, robotics, medical instruments, and military/avionics. These applications will expand the production capabilities for flash devices and drive the lower costs that will allow them to compete against

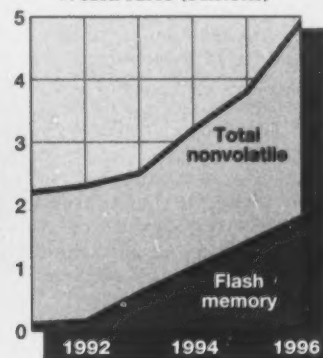
Not a Flash in the Pan

1991 Nonvolatile memory market



Source: Electronic Trend

World sales (billions)



Current interest in nonvolatile memory devices is based on their capacity to replace optical or magnetic disk drives in portable computers.

conventional storage systems.

Intel's current flash chips are based on 0.8- μ m manufacturing technologies. Intel's recently announced joint

venture with Sharp Corp., Tokyo, is expected to develop the next generation of flash memory devices based on 0.6- μ m technologies. —Tim Studt

Foreign Firms Use More Technologies

Foreign-owned or affiliated (FOA) plants in the U.S. use a wider range of advanced manufacturing technologies than do U.S. manufacturers, according to a recent study by researchers at Rensselaer Polytechnic Institute, Troy, NY.

The study is based on manufacturing technology survey data made by the U.S. Bureau of the Census. This data included information on the use

of technologies, such as CAD, lasers, robotics, and sensor inspection, in more than 10,000 U.S. plants.

"Investment in new equipment per worker also is much higher in FOA plants than in domestic plants," says Show-Ling Jang, co-author of the study. "It ranges from 65% for computer manufacturers to 400% for higher investments [telephone manufacturers]." □

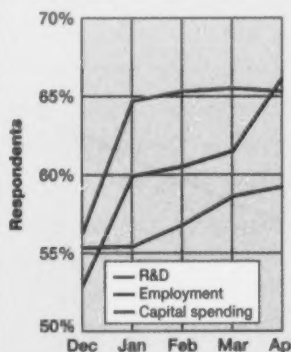
Business continues

Biotech Drives Bioreactor Growth



The global market for bioreactors is forecast to grow about 18% annually to just over \$200 million by 1996, according to Strategic Directions Intl., a Los Angeles-based consulting firm.

This growth will satisfy bioreactor demand by biotech, pharmaceutical, and other industries. Pilot-scale bioreactors account for nearly 80% of the total market.



Employment Improves

An improving economy increased confidence in the general employment situation in April, according to a survey by Cahners Economics, Newton, MA.

Almost two-thirds of the executives surveyed said they would increase or maintain employment over the next several months. Confidence in R&D stayed about the same as in March.

Researchers' Salaries Took A Beating in '91

R&D's survey shows that in most cases, scientists and engineers got skimpy raises—if any at all.

By John Morkes, Associate Editor,
R&D Magazine

R&D

Compensation packages are like politics: Everyone has an opinion. And, as with politics, a large-scale discussion about compensation can arouse a wide spectrum of feelings, from contentment to contentiousness.

The 4,984 respondents to R&D Magazine's annual salary survey made sure the entire spectrum was covered.

"My compensation package is perfect," said a corporate executive who makes more than \$100,000 a year and received more than five weeks of paid vacation last year.

"I feel exploited, overworked, poorly utilized, mismanaged, and undercompensated," said an electrical engineer who makes less than \$55,000 and did not take all three weeks of his paid vacation.

Most respondents were somewhere between the executive and the engineer, in terms of being satisfied with their salaries and benefits. Unfortunately, due to tight employer budgets, more respondents seemed to identify with the engineer.

One important reason is that 17.4%

of the scientists and engineers surveyed received no raise at all in 1991, compared with 11.2% the year before (see "Salary Increases" chart). And in many cases, those who received raises got a smaller percentage increase than in previous years.

Also, many employees were frustrated to learn that though they would receive salary increases, they would have to wait longer than usual for the raises.

"The period between pay raises has stretched out to between 18 and 24 months," a nuclear engineer said.

"Salary increases are deferred during tough times. Why isn't the time between raises ever shortened in good times?" asked a chemical engineer.

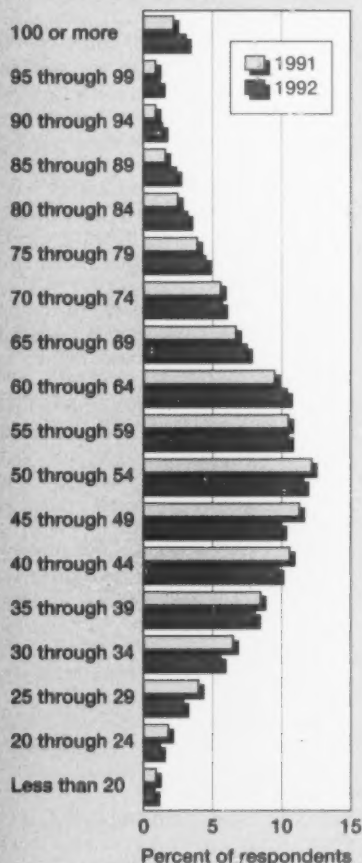
However, not everyone fared poorly in 1991. Physicists once again topped the list with the highest median salary—\$57,772—with nuclear engineers and aeronautical engineers close behind (see "Rankings" chart).

Forty-seven percent of the respondents' salary increases were above the 1991 inflation rate of 4.3%, as determined by Cahners Economics, New-

R&D Salary Survey: How Do You Measure Up?

All Researchers Compared	1991 Salary Raise Percentage (Percent of respondents)						1992 Salary Median	With Present Employer Median (years)	Age Median (years)
	Zero	< 2%	2-5%	6-9%	10-13%	≥14%			
Aeronautical engineer	8.5	—	70.7	14.6	4.9	1.2	\$57,341	13.2	48.2
Biotech/biologist	22.4	2.1	43.6	21.5	7.5	3.0	50,000	9.0	42.4
Chemical engineer	12.4	0.3	48.7	28.7	7.9	2.0	55,090	8.2	40.1
Chemist	13.7	0.6	47.8	28.2	7.1	2.3	51,550	9.0	41.6
Electrical engineer	21.4	2.3	47.3	20.0	5.8	3.0	52,045	7.6	41.7
Geologist	25.0	2.1	52.1	12.5	6.3	2.1	44,390	12.3	43.4
Industrial engineer	25.0	1.7	56.7	13.3	—	3.3	45,850	9.3	42.4
Materials	22.7	—	47.4	23.8	5.0	1.1	55,728	8.6	41.1
Mathematician	18.2	—	59.1	9.1	9.1	4.5	50,009	15.0	47.0
Mechanical engineer	19.2	0.6	48.0	23.8	4.8	3.5	51,380	7.7	40.6
Nuclear engineer	5.6	2.8	66.7	22.2	—	2.8	57,470	12.5	45.7
Physicist	17.7	0.6	50.7	24.1	6.1	0.9	57,772	8.3	43.0

Salary Levels for All R&D Workers (Thousands of dollars)



ton, MA (see "Salary Increases" chart). That's an improvement over 1990, when 43.9% beat inflation, and 1989, when the figure was 46.5%.

A minority of respondents had positive things to say about their compensation packages.

"The benefits and job security are great, the salary is enough to live on, and the work is exciting and interesting," said a government geologist.

"Our 'cafeteria' benefits plan is nice. Credits that are not used are paid as taxable income," an industrial chemist said.

Other comments were positive, but mixed with concern.

"My compensation package is so good that it may be cut back to save the company money," said a mechanical engineer.

Most comments, however, were negative and covered a range of subjects. A common complaint was that the respondents are overworked and underpaid.

"I receive low pay and no recognition for significant results and for taking on extra work," said an industrial chemist.

"During this age of 'doing more with less,' you pay the price for using vacation time. By the time you spend

copious amounts of unpaid overtime to allow yourself to take vacation, you are so mentally and physically drained that you spend the vacation recovering. I feel more like an indentured servant than the internationally known professional that I am," said an industrial engineer.

Respondents also complained about the way raises are meted out.

"How raises are determined is vague, arbitrary, and mysterious," a materials researcher said.

"Raises do not depend on merit. Only across-the-board raises are given unless you threaten to quit," said a chemist.

"Evaluation for increases is based more on publication numbers than substantive production," said a university professor.

Blame for inadequate compensation was often laid on incompetent managers.

"Compensation is being cut to pay for management's mistakes," said an electrical engineer.

"If we had competent management, we would make more profits and be able to afford better annual increases," another electrical engineer said.

Many researchers said that if they have to suffer poor compensation, then their bosses should, too.

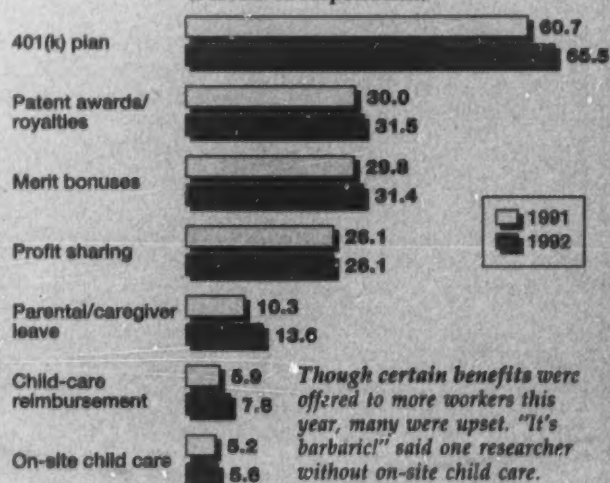
"My compensation is shrinking fast, but top management doesn't get hit as hard—they receive fat bonuses,"

Salaries for R&D workers in 1992 are about the same or slightly higher than salaries in 1991 (left), according to nearly 5,000 survey respondents.

Highest Academic Degree (Percent)

Experience Median (years)	<BS	BS	MS	PhD
23.5	3.6	32.5	47.0	16.9
16.2	1.8	18.1	21.7	58.5
13.4	5.4	33.5	34.1	26.0
14.5	4.9	34.2	19.2	41.7
13.2	15.8	32.3	35.7	16.2
17.1	4.1	16.3	34.7	44.9
10.9	36.7	38.3	16.7	8.3
15.1	7.7	23.7	29.2	39.4
19.2	4.5	27.3	45.5	22.7
13.7	14.2	41.8	31.3	12.7
21.0	2.8	25.0	22.2	50.0
17.9	4.3	16.3	26.0	53.4

Benefits for All R&D Workers (Percent of respondents)



Though certain benefits were offered to more workers this year, many were upset. "It's barbaric!" said one researcher without on-site child care.

'I never have to worry about the possibility of overcompensation,' a toxicologist said.

said a mechanical engineer.

"The executives get the big bonuses, good times or bad. We get the squeeze," said a materials researcher.

"The bonuses given to top management are too large. The money would be better spent if they gave larger incentives at the lowest levels," a chemical engineer said.

Some respondents felt that they are compensated less than other researchers for the same type of work.

"My overall salary is about half what I would expect for a similar job in industry," said a university chemist.

"If I were a man rather than a woman, I would be making several thousand more annually," an industrial hygienist said.

"After age 50, we are 'locked in' to retirement and get lower raises for the same responsibilities as younger workers," said a government chemical engineer.

Another subject of complaint was benefits, whose costs are being paid more by the employee and less by the employer, respondents said.

"It seems that every time the company makes 'improvements' to the benefits package, it ends up costing me money," said a nuclear engineer.

Salary Increases for All R&D Workers* (Percent of respondents)

Increase amount	1992	1991	1990
None	17.4	11.2	9.2
Less than 2%	0.9	0.9	2.1
2 through 5%	48.5	50.3	54.9
6 through 9%	24.6	27.2	24.7
10 through 13%	6.2	7.2	5.9
14% or more	2.4	3.2	3.2
Ahead of inflation	47.0	43.9	45.5

*Granted in year preceding that shown

A whopping 17.4% of researchers missed out on raises last year, while others received smaller increases than usual. Often, employees found their raises delayed several months.

Many researchers were unhappy that their employers did not offer "cafeteria-style" benefits packages that let employees choose their own benefits, up to a certain dollar amount.

Other respondents were critical of such a plan.

"We are shifting to a flexible benefits program. While this will result in great savings for the company, it will probably cost me about \$1,100 a year. This would reduce my 5.1% salary increase to 3%," said an industrial chemist.

The subject of health insurance generated angry comments because of

high cost to the employee, low coverage, and other reasons.

"Our health insurance program is so poorly defined that you must get sick to determine what it covers," said a university biologist.

A few respondents worried that their retirement and pension benefits might not be adequate down the road.

"With corporate buyouts and job security being what it is today, I will never see a pension or retirement check other than that which I provide for myself through 401 (k) and IRA plans. Who knows about

Social Security in 20 years?" said an industrial chemist.

Some researchers gave the impression that U.S. companies are no place for civilized scientists and engineers to work.

"My company has no on-site child care. It's barbaric!" a materials researcher said.

"Vacation policies in the U.S. stink. Any other civilized country gives more vacation," said an industrial chemist.

Several respondents showed they have a sense of humor about their compensation. When asked "What do you like best about your compensation package?" an industrial technician answered, "The paychecks don't bounce."

A government toxicologist answered, "I never have to worry about the possibility of overcompensation, and my lifestyle never makes my neighbors jealous." R&D

Copies of R&D's complete Salary Survey, with results presented in 71 tables, are available for \$150 each from Joan Cacioppo, R&D Magazine, 1350 E. Touhy Ave., Des Plaines, IL 60018; phone: 708/390-2734; fax: 708/390-2618.

Rankings by Median Salaries

Rank		Profession	Median Salary		Percent Change
1992	1991		1992	1991	
1	2	Physicist	\$57,772	\$58,062	-0.5
2	5	Nuclear engineer	57,470	55,010	4.5
3	1	Aeronautical engineer	57,341	58,393	-1.7
4	7	Materials	56,726	54,107	3.0
5	6	Chemical engineer	55,090	54,750	0.6
6	8	Electrical engineer	52,045	54,030	-3.7
7	9	Chemist	51,550	51,794	-0.5
8	11	Mechanical engineer	51,380	49,576	3.6
9	3	Mathematician	50,009	58,666	-11.7
10	10	Biotech/biologist	50,000	49,838	0.3
11	12	Industrial engineer	45,850	43,636	5.1
12	4	Geologist	44,390	55,500	-20.0

READER RESPONSE PANEL

Please rate your interest in this article by circling the appropriate number on the Reader Service Card.

High 464 Medium 465 Low 466

R&D SOFTWARE

Chemical Reaction and Equilibrium Computations

The Windows version of HSC software offers a quick and easy way to solve chemical reaction problems with a personal computer. All calculations utilize an automatically integrated thermochemical database that includes more than 5,600 compounds. The software helps to avoid expensive trial-and-error chemistry, allowing the chemist or engineer to set up optimum reaction conditions for experiments.

Outokumpu Research Circle 342

Collecting Weighing Data

BalanceTalk Jr. is a memory-resident (TSR) software program for collecting weighing data. The MS-DOS program transfers balance data into almost any other program. It works with all of the company's balances having a unidirectional interface. Setup is part of the program, so there is nothing to configure. The user simply loads the program and begins collecting weight data from the balance.

Mettler

Circle 344

Spectroscopy Upgrade

Version 3.10 of the DM3000 spectroscopy software offers new features such as expanded control of the company's products, including skip scan on QuikScan diode arrays, image storage, and gray scaling for Spectrum One CCDs, support of the Fluoromax and the 270M spectrometer. New laser printer and mouse capabilities have been added.

SPEX Industries

Circle 343

CE Control

SpectraPHORESIS software for capillary electrophoresis control is now available for other IBM-PC compatible computers. The new software will run on the Spectra 386 computer, giving users of the company's Analytical CE greater flexibility in their choice of computers. It controls the CE and provides method control and data reduction for CE analysis.

Spectra-Physics

Circle 341

Free PC System Configuration Tool

DAQ Designer is the first computer-aided system configuration tool for PC-based data acquisition. It is an in-

teractive and easy-to-use package with a graphical user interface that asks the user questions about system requirements, and then recommends specific plug-in data acquisition boards, signal conditioning products, cable assemblies, and software packages that can be used to develop the desired data acquisition system. And best of all, it's free.

National Instruments

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ABP BPA

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July 1992

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R&D

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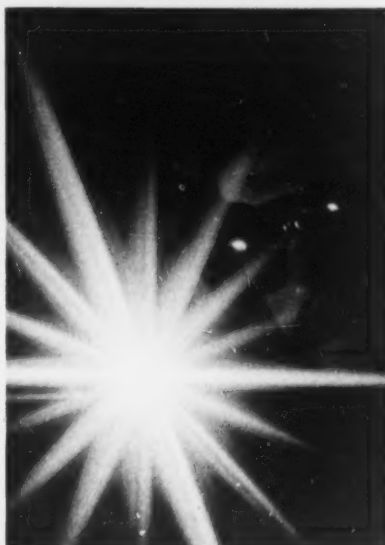
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Making the Right Choice
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ABOUT THE COVER Aniline-blue stained cross section of an asparagus root at 25 $\times$ using fluorescence was made by Mark Brundrett at the Soil Science and Plant Nutrition Center, Univ. of Western Australia. Photo: Nikon. See article, page 32.

R&D

The International Magazine of Research and Development

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MICROSCOPY

Add Video to Your Microscope For Even Better Imaging 32

By enhancing your optical microscope with a video system, you'll get much more information from your specimens.

R&D AWARDS

D. Allan Bromley—Point Man For U.S. Technology 40

This award-winning physicist is an unflagging, effective proponent of federal and civilian R&D—and he has George Bush's ear.

COMPUTERS

Parallel Supercomputers Tackle Tough Research Questions 48

Scalable supercomputers are helping researchers solve problems too big and complex for conventional systems.

SPECTROSCOPY

Dr. Raman's Legacy Shines With Renewed Interest 56

Raman spectroscopy may be worth another look because of dedicated instrumentation and a host of exciting new applications.

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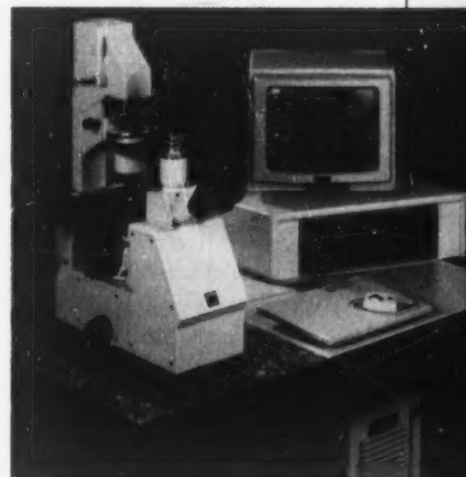
Glycobiologists Prove the Biochemistry of Life Is Sweet 62

A new 'sweet science' studies how sugars affect protein recognition in viruses and cells, with practical implications for therapeutics.

VACUUM TECHNOLOGY

Do Your Homework Before Choosing a Cryopump 67

First, calculate your gas pumping requirements precisely. Then check out these new pumps from Semicon/West.



Video microscopes, page 32

R&D BUSINESS

Parallel Computing Market Emerging

High-performance computing is the second fastest growing computer area today with more than \$27 billion in sales in 1991. It trails only network computing, according to a recent study by Electronic Trends Publishing (ETP), a Saratoga, CA, market research company.

Within high-performance computing, parallel systems are growing faster than all the rest, including conventional vector-multiprocessor and scalar/vector systems.

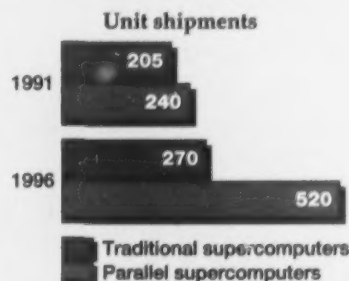
Not surprisingly, the two biggest names in high-performance computing, Cray Research and IBM, have recently announced plans to develop commercial parallel systems. Cray is developing a system that could consist of as many as 1,024 microprocessors, with first versions available as early as 1993. Cray's system will use Digital Equipment's new Alpha microprocessor for each node.

IBM's system is based upon its RISC (reduced instruction set computing) technology. Program managers for both systems are setting their sights on obtaining 1 teraFLOP performance within the next several years.

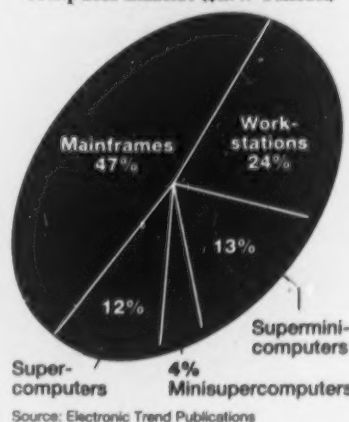
Oddly enough, applications for parallel computing are extending beyond traditional scientific areas, as more businesses begin to use this approach to sift through huge amounts of data. American Express, for example, uses its parallel computer to support its travel services business, and Kmart uses its parallel machine to develop new marketing strategies.

Software problems concerning how

Rapid Growth for Parallel Computers



1991 High-performance computer market (\$27.7 billion)



Parallel computers have the best growth in the high-performance computing market, with twice as many units forecast to be sold in 1996 as in 1991.

to coordinate all of a parallel machine's microprocessors remain the largest obstacle to large-scale applications. Each program still needs to be individually developed.

For additional information on parallel computing, see Justin Rattner's (Intel) feature article elsewhere in this issue. For more market information, ETP's report, *Parallel Processing/High Performance Computing—A Strategic Market Assessment*, (\$1,500) is available by calling 408/996-7416.

—Tim Studt

Economics Slow Japanese R&D

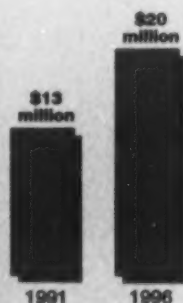
The slowdown in Japan's economy is hitting R&D spending. Corporate earnings in fiscal 1991 are thought to have declined for the first time in the last 10 years, and the current fiscal year is expected to be even worse.

The economy entered a recession in the last quarter, and predictions as to when it will pick up are mixed. While Japanese companies try to maintain R&D spending even in a downturn, the rate of spending growth is slowing.

According to a survey by Nihon Keizai Shimbun, a newspaper publisher, the estimated increase in R&D spending by manufacturers in the fiscal year through March 31 was 9.5%. Through the late 1980s, R&D spending went up 12% or more annually.

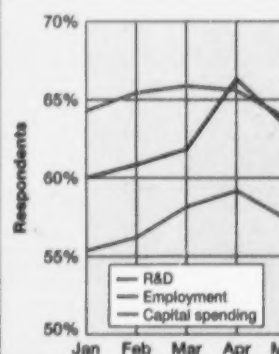
"R&D will go up a little with salary increases, but we won't see equipment budgets expanded in this fiscal year," says Steven Myers, a high technology

Renewed Interest in Raman



The market for dedicated Raman instruments and FTIR spectrophotometers with Raman accessories is forecast to grow 9% annually to more than \$20 million in 1996, according to Strategic Directions Intl., a Los Angeles-based consulting firm.

Although the current market for Raman instruments is small, use in areas other than research is driving this growth, says SDI.



Confidence Softens

Executives' confidence in their ability to maintain business efforts over the next few months softened in May, according to Cahners Economics (CE), Newton, MA.

This doesn't mean overall economic conditions will soon decline, says CE. More than half the firms rate current conditions as good—the same number as in April.

R&D BUSINESS

stock analyst with Tokyo-based Jardine Fleming Securities Ltd. But, a wholesale cutback is not expected either, according to Myers.

In a report to the Japanese prime minister, the Council for Science and Technology, an advisory body, called for the government to double spending on R&D and to strengthen basic research at Japan's universities and research institutes. —Dennis Normile

Law Slows Clinical Instrument Growth

Confusion over the U.S. Clinical Laboratory Act of 1988 (CLIA 88) has dramatically slowed growth in the once-thriving clinical lab instrument market, according to a recent study by Market Intelligence Research Corp., a Mountain View, CA, marketing research firm.

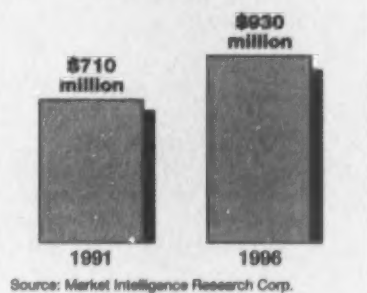
CLIA 88 placed stringent new regulations on laboratories concerning quality assurance standards, proficiency testing, and personnel guidelines. All this has caused users to postpone new instrument purchases until

uncertainties about the new rules are resolved.

However, the new law also sped development of new instruments with higher throughput rates, greater reliability, accuracy, and ease of use. New lower-cost analytical instruments for checking body fluid chemistry incorporate various technologies to maximize output.

For a copy of the study (\$1,895), call 415/961-9000. □

Clinical Lab Instrument Growth Slows



Sales of clinical laboratory instruments are increasing about 5.5% annually, down from nearly 7% in 1988 before new regulatory laws took effect.

Industry, Academia Must Work Together

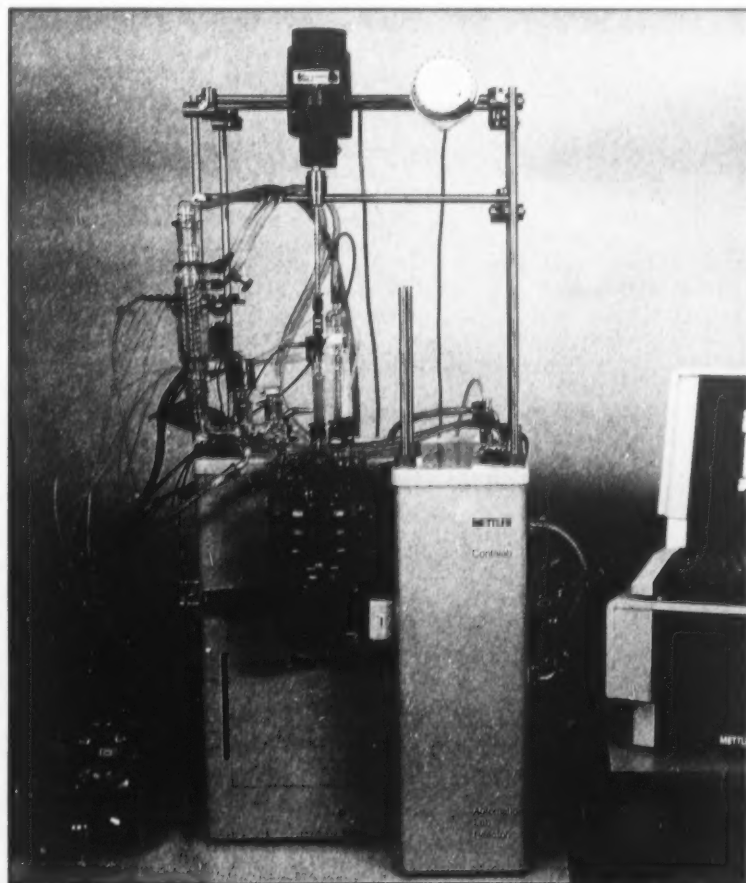
Transferring technology from the campus to the marketplace is key to staying competitive in the global market, says Dorin Schumacher, an administrator at Purdue Univ., West Lafayette, IN.

"Many countries, such as Japan and Germany, already know how to transfer technology from academia to industry," she says. "The countries that will be successful competitors will be those that are best able to move ideas from the lab to the marketplace."

In her new book *Get Funded! A Practical Guide for Scholars Seeking Research Support from Business*, Schumacher advises researchers on how to form partnerships with industry.

"While federal funding for university research is clearly defined, the path between industrial funding and universities is obscure," says Schumacher. Additionally, federal research funding is becoming harder to obtain, so researchers increasingly are seeking relationships with industry as a means of obtaining funding.

Schumacher's book (\$18.95) is available from Sage Publications Inc., Newbury Park, CA. R&D



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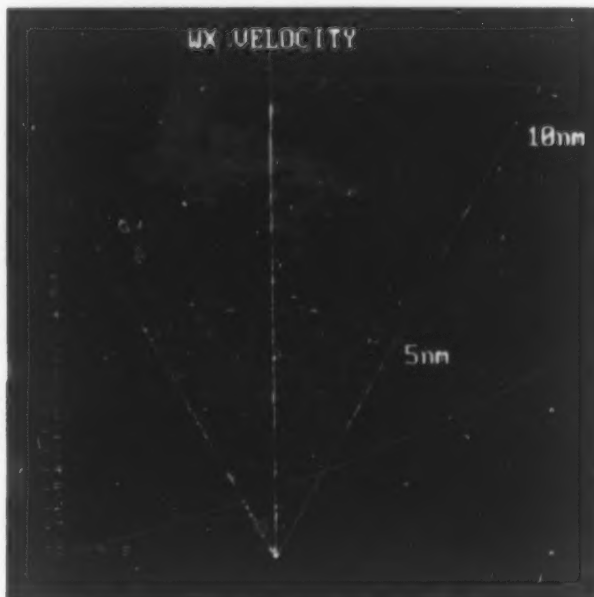
Windshear Detection Advances

Interest in developing new technologies for windshear detection and avoidance is growing fast. One incentive is the potential multibillion dollar market that will result from U.S. Federal Aviation Agency regulations requiring airlines to install such equipment by the end of 1993.

The FAA guidelines stem from the desire to avoid tragedies such as the 1987 crash of a Delta Airlines jet trying to land at Dallas-Fort Worth Airport.

A major question is whether such systems should be "reactive" or "predictive." In the past, available designs have been reactive types, which signal the flight crew that an aircraft has entered a windshear region.

Unveiled at the recent Asian Aerospace '92 Show in Singapore were some of the first predictive formats, such as the Windshear/CAT Prediction System from Rosemount Inc.'s Aerospace Div., Eden Prairie, MN, and the RDR-4B forward-looking detection and avoidance system under study at Allied-Signal Aerospace's Bendix/King Air Transport Avionics Div., Fort Lauderdale, FL.



This windshear detection system from Bendix/King shows relative speed of radar returns with respect to the ground. Negative velocities indicate movement toward the aircraft.

The Rosemount system is a forward-looking passive infrared (FLIR) sensing system that measures air temperature and water vapor concentration in front of an aircraft to determine whether windshear or significant clear air turbulence is imminent.

The Bendix/King concept is radar-based. Company engineers told R&D

the system essentially is an upgrade of the RDR-4A weather radar system, with an advanced microprocessor and new antenna. The system penetrates weather systems and detects windshear phenomena, also called "microbursts," in rain at altitudes under about 2,500 ft.

Near the ground, a downward-moving microburst splits into two wind flows, one accelerating toward the airplane, the second in the other direction.

"Doppler technology is used to measure the difference between the accelerations of the winds moving in opposite directions," says Ron Carlson of Bendix/King. "If a microburst is detected, a warning [of two to three minutes] is given to the pilot." Colors on the radar display show whether the hazard is mild (green), medium (yellow), or severe (red).

Bendix/King's designers claim their system is much more effective than alternatives such as FLIR and the Doppler-based technique called LIDAR. And retrofitting FLIR, they say, requires cutting a hole in the fuselage to mount the sensor.

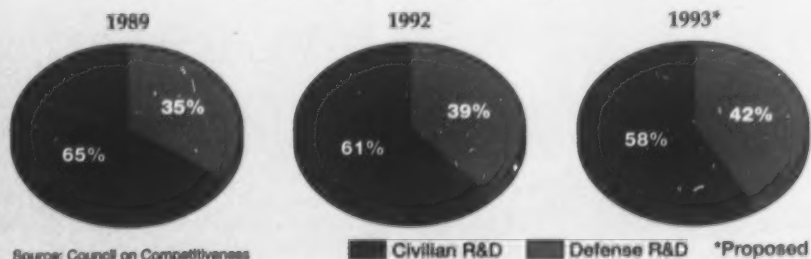
But a problem with the radar approach is that if a microburst occurs directly in front of the plane, the radar won't see it. While that isn't likely to happen very often—microbursts in general aren't very common—it is something the FAA must mull over. As Carlson noted, "The question remains: If an operator has a predictive system, will he also need a reactive one?"

By the same token, until now the reactive systems have had the field to themselves. So it might also be asked, If an operator has reactive, does he also need predictive?

Both approaches have advantages and disadvantages. Rosemount engineers agree that in the future, combined reactive/predictive systems may prove the most attractive option for airlines.

—Irwin Stambler

Civilian R&D Takes Larger Piece of Federal Pie (Percent of U.S. fiscal year budget)



The proposed fiscal year 1993 budget for U.S. federal R&D spending continues the trend toward more for civilian R&D and less for defense R&D.

R&D SOFTWARE

Thermal Image Analysis

ERIKA 2.0, a new software version for the company's Thermovision 900, adds a "thermal workstation" designed for scientists and engineers performing advanced research and quality control. It allows the plotting of time vs. temperature for up to three points on an image.

Agema

Circle 342

FT-IR Spectral Searches

Model 1650 FT-IR Spectrometer is a revised version of the company's 1600 Series. The new software has spectral interpretation and searching features. The revised software also provides the ability to select among peak match, interpretation, EXPERT, and Euclidian distance algorithms.

Perkin-Elmer

Circle 343

EZChrom Upgrade

EZChrom Version 1.1 is a software upgrade of the company's EZChrom Chromatography Data Acquisition and Control System. It includes com-

patibility with the LC and the GC chromatograph control packages. Features include: bracketing calibration functions, new append function for batch operations, extensive real-time feedback, improved printing speed, and user log-in and audit trail.

Shimadzu

Circle 344

Real-Time DSP Support

LabWindows Version 2.2 is a development system for DOS-based data acquisition and instrument control applications. The software now features enhancements to the analysis libraries for real-time digital signal processing, the User Interface Library for interactive graphics, and to the data acquisition library for support of the SCXI signal conditioning system.

National Instruments

Circle 340

Environmental Analyses

The Enviropro software for the company's Saturn II GC/MS systems performs multiple calculations automatically and generates report forms similar to the EPA CLP 3/90 statement of work (SOW). It also verifies that EPA mass spectral tuning criteria of BFB and DFTPP are met.

Varian Associates

Circle 341

CIRCULATION

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Tomorrow's Hot New Material

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Finding Many New Uses

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Bright Future on Horizon
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ABOUT THE COVER Firefighter's helmet molded from blend of polyetherimide and polycarbonate meets new 1992 safety standard for impact and fire retardance. Photo: GE Plastics

R&D

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FEATURES

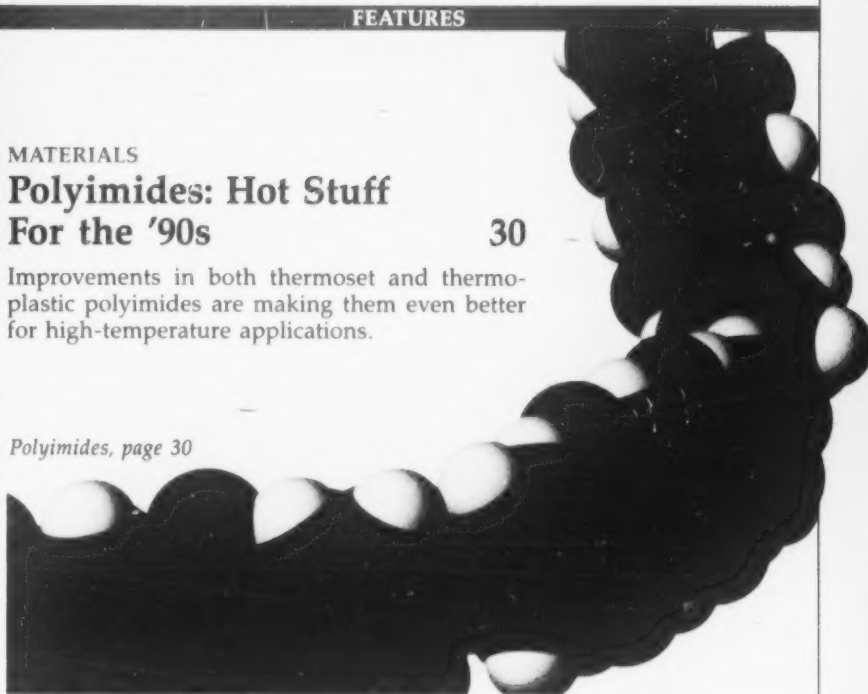
MATERIALS

Polyimides: Hot Stuff For the '90s

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Improvements in both thermoset and thermoplastic polyimides are making them even better for high-temperature applications.

Polyimides, page 30



ENVIRONMENTAL RESEARCH

High-Tech Windmills' Future Burns Bright

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Modern windmill design blends materials science, turbulence theory, and aerodynamic engineering. It's not simple, but it is turning on more and more light bulbs.

ANALYTICAL CHEMISTRY

New CE Applications Deliver Sweet Separations

42

Capillary electrophoresis is making great strides in solving longstanding problems, from identifying food additives to detecting herbicides.

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Cryo Regeneration Times Keep Getting Shorter

47

Cryopump makers and users alike are resorting to a variety of techniques to reduce regeneration time to under three hours.

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R&D BUSINESS

R&D's Spending Elite Hold Their Own

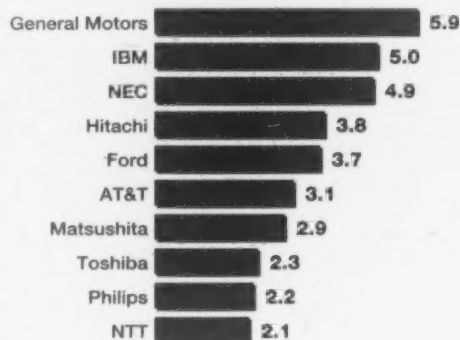
The biggest R&D spenders continued their hold on the top spots in 1991 with only minor shuffling of positions from the spots they held in 1990, according to a recent study by Schonfeld & Associates, Lincolnshire, IL. In fact, nine of 1991's top 10 spenders have been there for the past five years.

However, Schonfeld predicts continued incursions into U.S. top positions by foreign companies. Japan's NEC is expected to outspend IBM in 1993 by almost \$100 million.

For a copy of *R&D Ratios & Budgets*, (\$325), call 708/948-8080.

How Top R&D Spenders Stack Up

1991 Outlays (billions)



Source: Schonfeld & Associates

Japanese Science City Inspires Imitator

The success of Japan's Tsukuba Science City near Tokyo has led civic leaders in the Osaka area to plan a science city of their own. This development, Kansai Science City, however, is expanding upon Tsukuba's focus by including organizations that are involved in researching culture, economics, and the arts.

The centerpiece of Kansai's interdisciplinary approach is the International Institute for Advanced Studies. Modeled on Princeton (NJ) Univ.'s Institute for Advanced Studies, Kansai's institute plans to have research programs in the natural and social sciences and humanities. The Kansai in-

stitute has an endowment of about \$40 million, and its research-residential complex is scheduled for completion in early 1993.

Kansai Science City is about halfway between Osaka and Tokyo, adjacent to the ancient city of Nara. About 30 facilities are already operating at Kansai, with several hundred more expected early in the next century. Total investment is expected to be more than \$30 billion. Initial investments have come from a mixture of public and private sources.

Tsukuba's first research institute was completed 24 years ago. Tsukuba now has 58 government-affiliated re-

search facilities which employ about 10,000 researchers. These labs receive about half of the funding the Japanese government has budgeted for national research facilities.

There also are 168 private research centers involving 221 industrial organizations within Tsukuba Science City and still more in the surrounding area. Of Japan's 47 prefectures, 17 maintain liaison offices in Tsukuba.

—Dennis Normile

Reports Give Info On Foreign Research

Who would you contact to find out about metallurgical research in China? You might try Zhou Rong Chang at the Jiangsu Metallurgy Research Institute in Ganjian. But, if you didn't know that very specific bit of information, you might have some trouble determining where to go.

Two recently published management guides to foreign technology can help you with this type of information, along with other foreign research opportunities. These reports include sections on foreign publications, cultural guidelines, and how to set up foreign marketing strategies. They also contain directories of foreign businesses and technology centers and associations, what they do, and who to contact.

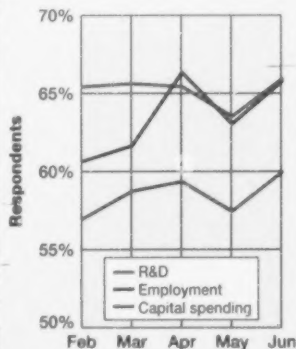
For a copy of *How to Find and Exploit International Technology Opportunities—Volume 1/Europe*, or *—Volume 2/Asia, Pacific Rim* (\$585 each), call Technical Insights Inc. at (201) 568-4744. **Circle 377**

Moderate Rheology Growth



The market for viscometers and rheometers in R&D and quality functions is forecast to grow about 8% annually to more than \$180 million in 1996, according to Strategic Directions Intl., a Los Angeles-based consulting firm.

Sales growth of rheometers is expected to be twice that of viscometers, which is attributed to the increasing sophistication of rheometer features and capabilities.



R&D Rebounds

Following a slight dip in May, corporate confidence in R&D, employment, and capital spending rebounded in June to record high levels, according to a survey by Cahners Economics, Newton, MA.

Almost 68% of the 400 corporate executives indicated that they would maintain or increase their R&D efforts over the next several months.

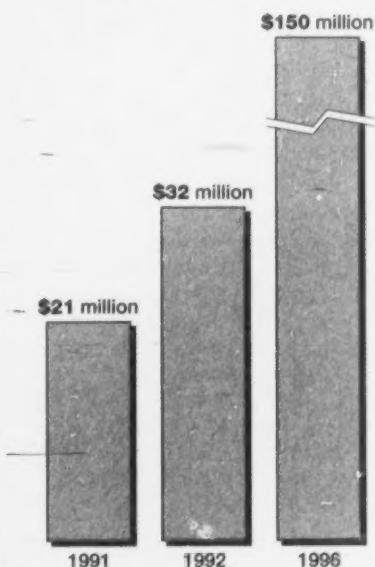
New CE Applications Deliver Sweet Separations

Capillary electrophoresis is making great strides in solving longstanding problems, from identifying food additives to detecting herbicides.

By Howard J. Goldner, Associate Editor, R&D Magazine



CE Annual Sales Expected To Grow 48%



Source: Strategic Directions Intl.

New uses for CE should prompt a substantial rise in instrument sales.

For the past decade, capillary electrophoresis (CE) applications have focused primarily on protein, peptide, and amino acid analysis, with little work being conducted on smaller molecules outside the biochemical area.

Now, however, thanks to lively scientific conferences, such as HPCE '92 held recently in Amsterdam, Netherlands, a wide variety of additional uses for CE are becoming known. As a result, this convenient analytical technique is beginning to find its way into many new industrial surroundings.

At HPCE '92, scientists from the Hershey Foods Technical Center, Hershey, PA, presented many examples of their use of CE in the analysis of food. Several of these have the potential of becoming routine quality control procedures.

Among the CE-based test methods they discussed were the determination of glycyrrhizic acid in licorice root extract, analysis of cocoa for caffeine and theobromine, the determination of vitamin C in citrus and other fruit beverages, and the measurement of niacin in peanut butter extract.

Using a prepared standard, they also demonstrated the feasibility of separating the mycotoxin sterigmatocystin, a potential carcinogenic precursor. In a similar way, they readily separated a mixture of several water-soluble vitamins, including niacin, thiamine, riboflavin, vitamins C, B-6, B-12, and folic acid.

Further studies led to more exciting breakthroughs. "The separation of seven commonly occurring food ingredients—caffeine, theobromine, vanillin, ethyl vanillin, aspartame, sorbate, and benzoate—in a single run is truly remarkable," says W. Jeffrey

Hurst, Hershey Foods' senior staff scientist.

"CE is especially advantageous because it allows a rapid changeover from one component type to another," continues Hurst. "Not seen with many other analytical techniques, this feature allows the serial determination of different components in different samples without the need to switch columns or buffer systems."

"These CE methods are faster, easier, and at least as sensitive as what we have in place now. This capability allows the analyst to respond to production and consumer concerns in a timely and efficient manner. CE has excellent potential for the food analyst," notes Hurst.

On a different front, agrochemical scientists are beginning to use CE for the analysis of pesticides. Although many methods currently exist for the analysis of pesticides in raw agricultural commodities and environmental samples, most of these use gas chromatography or HPLC coupled with a variety of detectors.

Recognizing the need for rapid and sensitive methods for herbicide analysis, researchers at the Laboratory of Instrumental Analysis, Eindhoven Univ. of Technology, Netherlands, have developed a technique to separate the toxic chlorophenoxy acid herbicides by micellar electrokinetic capillary chromatography (MECC).

This research team, led by Quanji Wu, was able to easily separate a mixture of 10 chlorophenoxy acids within 10 min. They also found that selectivity could be fine-tuned by using different combinations of surfactants to achieve even greater separations.

The MECC approach avoids the extensive preparation of surface water,

urine, soil, or sediment samples which HPLC analysis of herbicides usually requires.

U.S. federal and state regulatory agencies now require industry and agrochemical manufacturers to develop suitable methods to monitor their pesticide materials as they are commercialized.

Relatively new among these products is an environmentally safe class of herbicides known as imidazolinones.

Scientists at American Cyanamid Co., Princeton, NJ, have recently begun using CE in the analysis of agri-

cultural and environmental samples for these imidazolinone herbicides, and have obtained results that compare closely with traditional analytical methods such as GC and HPLC.

Moreover, the CE technique is especially attractive since it avoids the use of organic solvents and their associated disposal problems.

These imidazolinones kill plants by inhibiting acetohydroxyacid synthase (AHAS), an enzyme common to the biosynthetic pathway of the branched-chain amino acids valine, leucine, and isoleucine. This inhibition disrupts protein synthesis, which, in turn, interferes with DNA synthesis and cell growth.

Animals do not have any AHAS and do not synthesize these three amino acids. This partially explains the low toxicity of the herbicide to mammals and other non-target ani-

mal species in the environment.

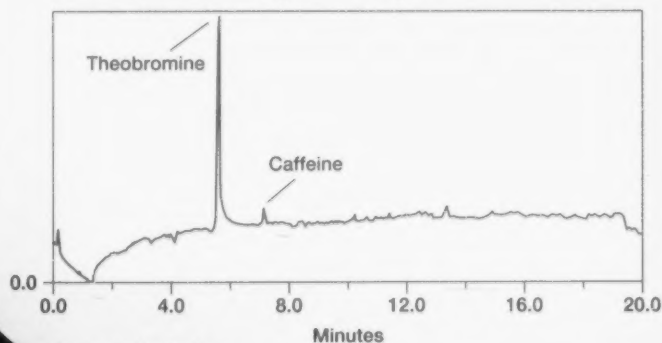
Since imidazolinones and their metabolites may remain in soil, water, and crop commodities, manufacturers are required to have assay methods available for residue detection.

"CE yields high resolution separations of these herbicides in crop samples within minutes, using only nanoliter sample volumes," says Max Saffarpour, a research chemist at American Cyanamid. "Because extensive sample cleanup procedures are minimized as compared to other techniques, I expect CE to become a valuable tool for residue chemists in the near future."

Capillary electrophoresis has developed into a powerful tool for separating ions as well as neutral analytes because of its remarkable separation efficiency.

In an effort to augment these capa-

CE Allows Rapid Analysis of Cocoa



Source: Hershey Foods

Many helpful analytical methods for rapidly determining food constituents have been developed with the CE technique. (Photo: Hershey Foods)

'CE is faster and more sensitive than anything we have now. It has excellent potential for the food analyst,' says an industry expert.

bilities, researchers at Millipore, Milford, MA, have recently developed a new technique that combines HPCE and membrane technology. The system recovers the separated species for further analysis. This is in contrast to normal practice, which is to simply discharge the analytes into a reservoir.

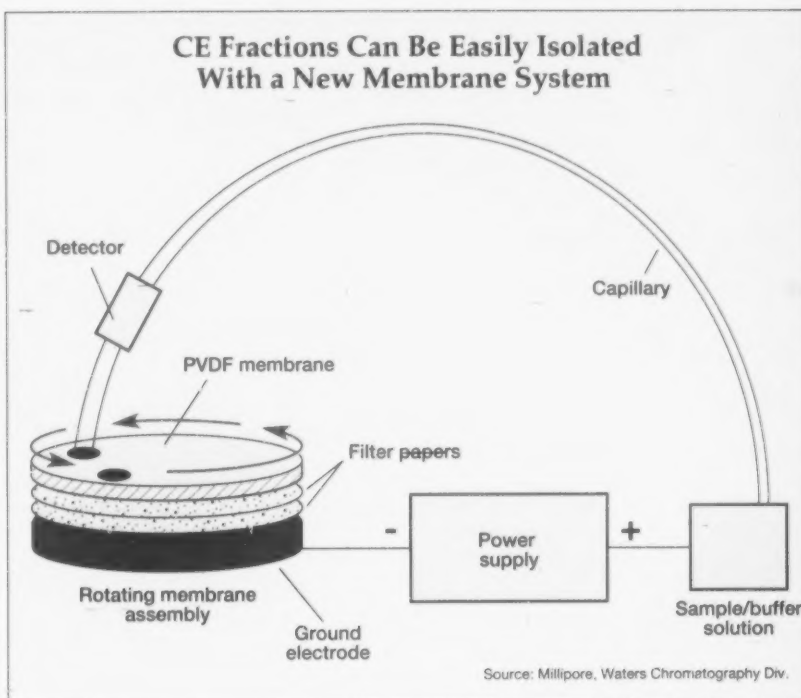
Previous attempts to collect these CE fractions have included using small vials to sequentially capture the eluted species, but this technique proved unsuccessful. It generally resulted in significant sample dilution or was too difficult to obtain closely spaced sample bands in separate vials.

Another approach to collecting eluted fractions is to carefully construct an on-column frit near the exit end of the capillary. The electric circuit is then completed through this frit.

This method minimizes the dilution effect. However, it is difficult and time consuming to make the frit, and it functions only when electroosmotic flow is in the right direction.

Millipore's experimental CE fraction collector consists of a membrane assembly placed in contact with the exit end of the capillary. The assembly comprises a polyvinylidene difluoride (PVDF) membrane cover, a buffer reservoir consisting of two layers of 3MM chromatography filter paper, and a stainless steel plate. The plate completes the electrical circuit for electrophoretic separation by acting as the ground electrode.

The entire collection assembly is rotated by a stepping motor at 2.2 revolutions per hour while electrophoretic separation takes place. Analytes are deposited onto the membrane at discrete locations as they emerge. The



A new fraction collection system combines HPCE and membrane technology to provide an effective means of obtaining analytes as they are separated and eluted from the capillary, making further treatment of the species possible.

collected fractions can be either stained in place or removed from the membrane for further treatment.

Since the analytes are deposited onto the porous membrane substrate, they are in a form that permits further analysis by a variety of presently available techniques, including staining, immunoassay, ELISA, amino acid sequencing, DNA probes, and chemiluminescence.

In principle, the membrane can be engineered to trap or bind virtually any species that can be separated by CE to allow these species to be subjected to further analysis.

To demonstrate the feasibility of this technique, the research team performed direct protein sequencing of two recovered proteins following CE separation.

Capillary electrophoresis is moving from a research technology to becoming an accepted analytical tool with a seemingly unlimited range of applications. Methods development is expanding rapidly also as scientists try the technique and quickly discover the many benefits it possesses over existing systems.

R&D

CE Manufacturers

For more information on capillary electrophoresis equipment and supplies, circle the appropriate numbers on the Reader Service Card.

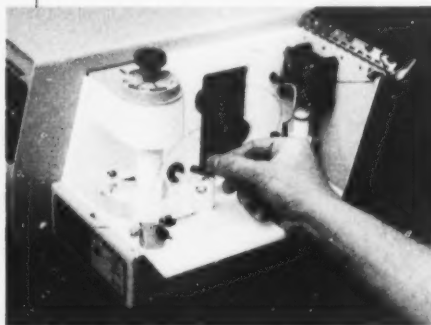
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Space limitations preclude listing all manufacturers of this equipment. For further information, see the R&D Magazine Product Source.

READER RESPONSE PANEL

Please rate your interest in this article by circling the appropriate number on the Reader Service Card.

High 471 Medium 472 Low 473



Isco's quick-change capillary holder and three different injection modes allow increased flexibility for many applications.

IRSD SOFTWARE

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GRAMS/386 runs under Microsoft Windows and can acquire data from hundreds of analytical instruments, streamlining data viewing and processing chores. Data processing capabilities include curvefit, subtraction, quantitative analysis, peak picking, integration, and a variety of chemometric procedures. A three-dimensional,

fully relational database offers complete laboratory data management. The database transparently organizes gigabytes of spectroscopic, chromatographic, and other analytical data.

Galactic Industries Circle 349

Automatic Line Follower

UnGraph Version 2.0 features an automatic line follower enabling accurate output of X,Y coordinates of graphs and lines. It has an automatic grid removal and compensation for log axes and skewed baselines. Paint and eraser tools enable repairs or in-

terpolations on scans. The single-point digitizer is useful for digitizing scatter diagrams and histograms and identifying height and position of selected peaks of chromatograms, etc. Applications include computer-aided design and the automatic conversion of chart recordings to numbers.

BIOISOFT Circle 351

PC/IR Enhancement

Version 3.2 is the company's improved PC/IR program that operates in Microsoft Windows for easy FT-IR operation and improved report generation. Its new features include faster menu speed, Autogain, print preview command, stacked display command, a Cosine Apodization function, and Forman phase correction.

Nicolet Circle 343

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"Wheel! Who needs a wheel?
What we need is a comb!"

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September 1992

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R&D

Research & Development

ELECTRONIC TESTING

Envisioning Your System

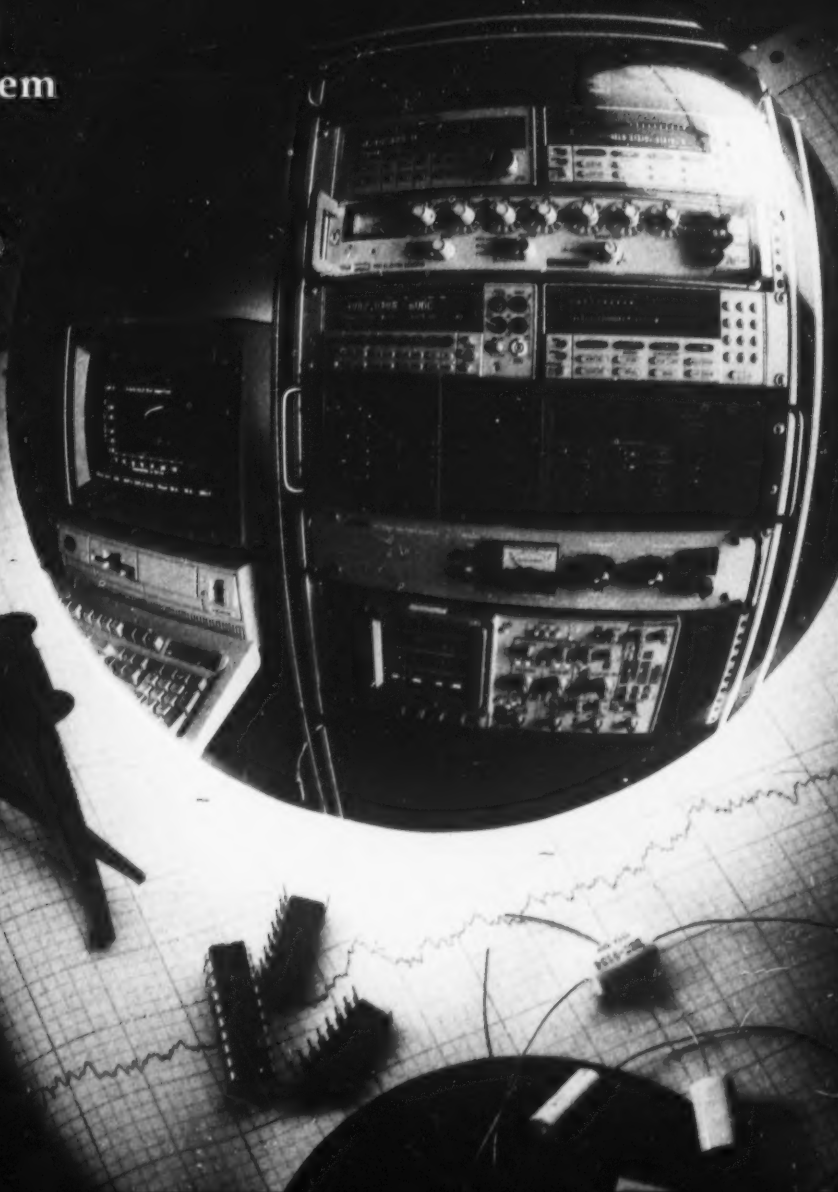
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NOAA's Susan Solomon

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Making Artificial Blood

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ABOUT THE COVER Gaze into our crystal ball and see the right way to design your test and measurement system—without the source errors. Photo: Keithley Instruments, Solon, OH.

R&D

The International Magazine of Research and Development

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TEST & MEASUREMENT

Envisioning Your Test System? Watch for Error Sources!

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Peer into this expert's crystal ball and learn how to penetrate the mysteries of designing a test and measurement system.



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How Susan Solomon's Research Changed Our View of Earth

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The NOAA chemist who discovered a critical link between CFCs and the ozone hole and then tested her theory in Antarctica has been named *R&D Magazine's* 27th Scientist of the Year.

BIOTECHNOLOGY

Pulse Quickens In Search for Blood Substitute

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Substitutes that mimic blood's oxygen-carrying ability are racing to obtain FDA approval. The substitutes are free of HIV and hepatitis.

VACUUM TECHNOLOGY

Selecting a Dry Pump Is No Easy Matter

63

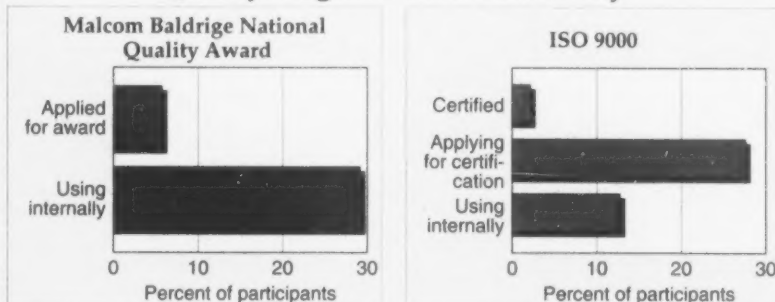
You should talk to users as well as dry pump makers to zero in on the cost of ownership.



Artificial blood, page 54

COMING IN OCTOBER ... The R&D 100 Awards program celebrates its 30th Anniversary, featuring the 100 most technologically significant new products, processes, and inventions of the year.

Quality Programs Do Double Duty



Source: American Electronics Assn.

Many companies use the Baldrige Award and ISO 9000 application criteria as internal quality manuals in addition to using them for an award or certification.

Getting Process Improvements From New Quality Programs Takes Time

Quality is the most important factor in the competitive success of high-technology companies, according to a recent survey by the American Electronics Assn., Santa Clara, CA. Quality was ranked first by 87% of the 456 respondents. Customer service was selected by 59% and having the latest technology was third with 43%.

The survey reveals that while 75% of the respondents are implementing total quality management (TQM) programs, relatively few have reduced the number of defects in their production output. The survey notes that the average number of in-house defects was reduced only 17% in 1992. A similar survey in 1988 revealed a larger defect reduction of 39%. The

survey noted that results from TQM programs historically take time.

Interestingly, the percentage of respondents using TQM programs dropped from 86% in 1988 to 75% in 1992. Use of other programs, such as computer integrated manufacturing also declined over the same period.

The survey also noted that the Malcom Baldrige National Quality Award and the European Community's ISO 9000 Series are being used increasingly as quality standards, with more than half of the respondents saying they are using one or the other.

For a copy of 1992 Productivity Survey (\$55), write to Pittiglio Rabin Todd & McGrath, 1503 Grant Rd., Mountain View, CA 94040. □

Ceramic Products Replacing Metal

Continuing Japanese ceramic research is leading to larger and more complex ceramic parts. NGK Spark Plug Co. and Garrett Automotive Group announced last December that they had jointly developed a large rotor for use in the turbochargers of Caterpillar Inc.'s 460-hp diesel truck engines. The rotor has a 96-mm OD and is made of sintered silicon nitride.

The new rotor is 40% lighter than a metal rotor and has a lower moment of inertia. This results in faster turbocharger response, according to NGK. The ceramic material also is more corrosion resistant than metal.

While other ceramic parts, such as valves and sensors, are increasing in use, research also is continuing on development of complete ceramic engines. Isuzu researcher Hideo Kawamura believes the higher combustion temperatures of ceramic engines will eventually result in lower NO_x emissions and boost fuel efficiency by as much as 30%. While the materials and structure of the ceramic engine are fairly well established, the engine design has combustion problems at elevated temperatures. Commercialization is years away.

Japan's Ministry of International Technology and Trade is supporting research into ceramic gas turbine engines in cooperation with major oil companies and automakers. The ministry expects to provide \$77 million over seven years. The project continues through 1997. —Dennis Normile

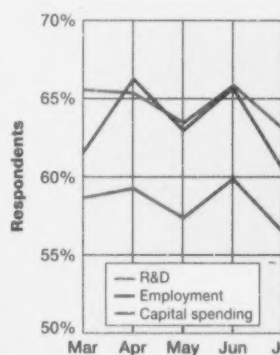
Business continues

Moderate Growth for SEMs



The market for scanning electron microscopes (SEMs) is forecast to grow nearly 6% annually to about \$300 million in 1996, according to a recent survey by Strategic Directions Intl., a Los Angeles-based consulting firm.

SEM sales make up about half of the total market for electron microscopes. One of the hottest current products is the environmental SEM which examines organic samples.



Confidence Wavers

Instability in the current financial environment lowered corporate executives' confidence in their ability to maintain R&D, capital spending, and employment, according to a recent survey by Cahners Economics, Newton, MA.

In July, about 63% of the respondents indicated they would maintain or increase their R&D efforts, a 2.8%-point drop from June levels.



New Boat Propeller Design Is Efficient

Alan Underwood of Brunton's Propellers Ltd., Sudbury, England, inspects the blades of the world's first self-pitching propeller, a device for boat propulsion.

In operation, the Autoprop propeller blades find an equilibrium position by balancing the hydrodynamic and centrifugal forces at each revolution, no matter which direction the propeller is turning.

That is, the blades automatically adjust pitch to deliver thrust at a reduced number of revolutions per minute, which saves fuel.

When the boat is under sail only, the propeller blades automatically feather to the water flow, adopting the line of least resistance, independent of the angle of the propeller shaft.

to determine the reason for the supplement's behavior.

The Mississippi program sought to find out why Ester-C showed more bioactivity than common vitamin C compounds such as ascorbic acid. When the tests pointed to threonate, it was something of a surprise, Verlangieri told *R&D*. Threonate had been known only as a component in the preparation of a certain kind of bread in England.

"When ascorbic acid was added to the bread, threonate was produced, which acted to reduce the time needed

to make the loaves," Verlangieri says. "It was known that threonate was a degradation product of vitamin C, but it was always thought it didn't do anything. Now we know that isn't true."

Once the researchers realized that threonate raised the bioactivity of Ester-C, possible uses were considered. The thought was that by adding it to other compounds, the cellular absorption rate might be increased.

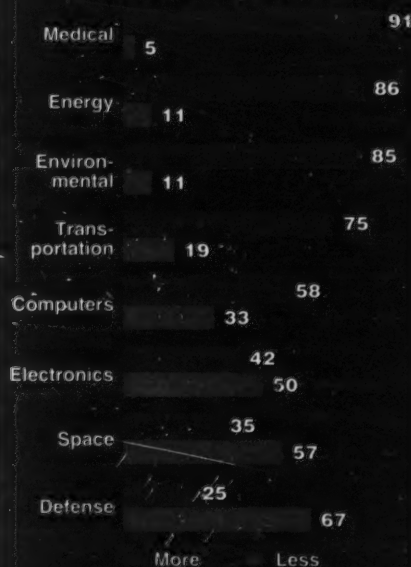
In early work, threonate was added to a variety of organic acids for evaluation. The tests indicated it provided a 50% to 200% absorption increase compared with nonthreonate groups in aspirin, the arthritis drug piroxicam, and vitamin C.

As part of a pilot study, Verlangieri's team drew up a list of hundreds of compounds, including antibiotics, amino acids, chemotherapeutic agents, and anti-inflammatories. Preliminary screening suggests that 25% to 50% of that list can achieve substantially higher cellular intake if threonate is added.

Much of the detailed work to date has focused on the aspirin-threonate system. The results indicate the system can offer an effective way to eliminate unwanted side effects.

Should the U.S. Spend More Or Less on Research?

(Percent of respondents)



A poll of 1,255 Americans found that 9 out of 10 support increased spending on medical research. One in four backs more spending on defense research.

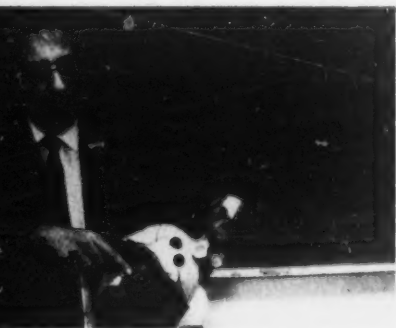
"Our thinking is that by greatly increasing transport and absorption in the gastrointestinal tract, lower doses of aspirin may be used to achieve the same medicinal effect," he says. "In essence you can take less of the drug and end up with the same therapeutic effect much faster than before." □

Superconductivity Protecting Against Power Disruption

Superconductivity Inc., Middleton, WI, has started marketing its Superconducting Storage Device (SSD), believed to be the first commercial use of superconductor technology for power applications.

The SSD protects industrial processes from power sags or voltage outages by sensing those conditions and supplying required extra power. (Power loads in the megawatt range are difficult to protect with other equipment, such as battery systems.) Once there is a disturbance, the SSD can supply full power to the load in 4 msec.

Product manager James Emerick



Anthony Verlangieri is studying threonate for use in drug delivery.

R&D SOFTWARE

LabVIEW Now for Windows and Sun

The LabVIEW graphical programming software, available on Apple Macintosh computers since 1986, is now available on IBM-compatible PCs running Microsoft Windows 3.1 and Sun Microsystems SPARCstations running MIT's X Window System or OpenWindows Version 3.

LabVIEW is a general-purpose programming tool that allows researchers to build software modules called virtual instruments, instead of writing text-based programs. Applications developed for either Windows or SPARCstations are completely portable to the other.

Both versions feature a library of ready-to-use controls, graphs, and strip charts for building custom interfaces and control panels. Icon libraries are available for controlling more than 100 GPIB, VXI, and RS-232 instruments. The Windows version also has a library for controlling data acquisition, signal processing, and signal conditioning hardware.



LabVIEW versions for Windows and Sun SPARCstations allow researchers to build control panels for various instruments using icon-based programming modules.

Compared to the Macintosh version, the Windows/Sun versions add a new sweep chart for faster plotting speeds, a fast waveform graph, and multivalued numeric controls.

LabVIEW for Windows requires a

386 PC with 387 coprocessor, 8-MB RAM, and DOS 5.0. LabVIEW for Sun requires 24-MB main memory and 32-MB disk swap space. It does not require Motif or OPEN LOOK.

National Instruments Circle 361

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ABP BPA

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R&D

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R&D 100 AWARDS

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ABOUT THE COVER Pacific Northwest Laboratory's award-winning process for synthesizing ceramic powders. See R&D 100 Awards, page 46.

R&D

The International Magazine of Research and Development

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COMPUTERS & SOFTWARE

Can High-Performance Networks Meet Future R&D Needs? 30

Network technology is racing to meet increases in computer technology and data generated by researchers eager to communicate it.

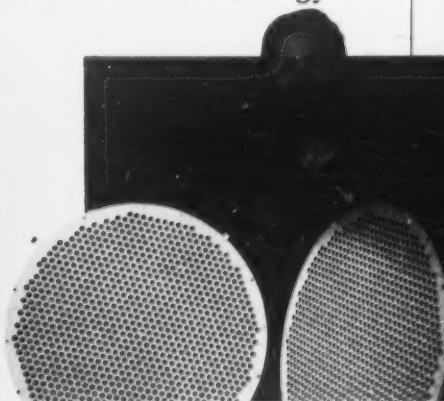
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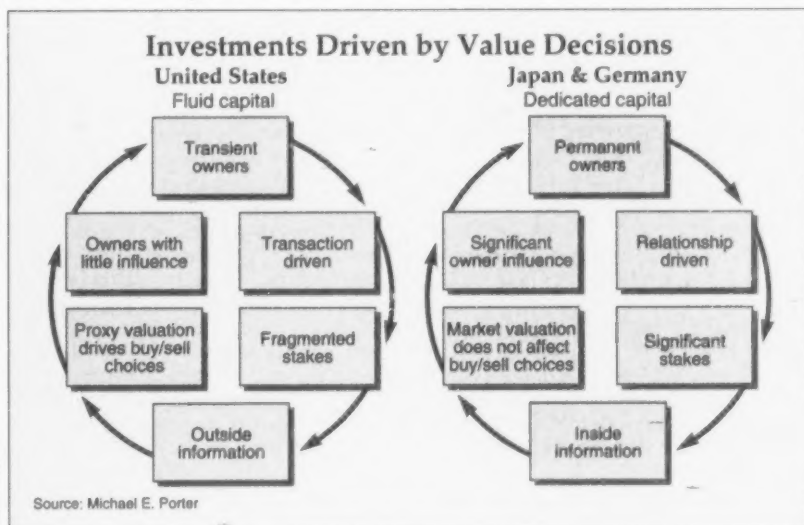
VACUUM TECHNOLOGY

Recent Advances Improve Auger Analysis 109

Smaller beam sizes and numerical analysis methods are increasing the performance and utility of Auger spectroscopy.

R&D BUSINESS

Link Competitiveness to Investment Choices



Capital is distributed differently in U.S. and foreign firms to meet the financial requirements of outside investors. U.S. capital decisions require faster paybacks.

Short time horizons, high capital costs, poor quality, and ineffective management are often listed as the primary reasons why many U.S. companies cannot compete with their foreign counterparts.

Not so, says a new report. They're only symptoms of capital investment policies in the U.S. The report, *Capital Choices*, by Michael Porter, a professor at the Harvard Business School, Cambridge, MA, states that investor objectives are the reasons why U.S. companies operate differently than those in Japan and Germany.

In the U.S., return on investment

and higher stock prices are the top two objectives of corporate owners, while improving products and market share are most important in Japan. Much of this comes about because many U.S. corporate owners are transient impersonal groups, such as pension funds, that base their investment decisions on superficial information. They also take no interest in company operations and have little influence on management behavior. These owners now own 60% of the equity in U.S. companies, compared to only 8% in 1950.

By contrast, Japanese and German

firms have owners that tend to be permanent and take a more active role in management and operations. About 70% of German and Japanese corporate owners are permanent who allow investment funds to remain in the companies for long periods of time.

For a copy of the report (\$42.50), call 202/785-3990. —Tim Studt

Environment Spurs Instrument Growth

Improvements in separation techniques and increased regulation of hazardous waste disposal continue to be the main drivers of analytical instrument growth in the U.S., according to a recent study by Market Intelligence Research Corp., Mountain View, CA.

The analytical instrument market increased more than 37% over the past four years to \$1.85 billion, for a compound annual growth of 8.3%. Average annual growth is expected to increase to 8.8% over the next six years.

Molecular analysis instruments are projected to show the strongest growth during the 1992 to 1998 forecast period.

By 1998, they will hold a 35% share of the total market, while elemental analysis instruments are expected to decline in market share over the same period.

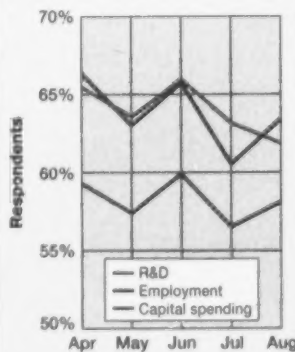
Average unit shipments of all instruments will rise at a slower rate than revenues, as increasingly sophisticated instruments with greater sensi-

DNA Instruments Booming



With an annual growth rate of more than 16%, DNA and protein sequencers are key growth sectors of the bioinstrumentation market though 1996, according to Strategic Directions Intl., a Los Angeles-based consulting firm.

DNA sequencers alone show a strong annual growth of nearly 18%. Protein sequencer sales are growing slower at 12%.



Opinions Mixed

Executives' confidence in their business plans were mixed in July, according to Cahners Economics, Newton, MA.

About 62% of the 400 executives surveyed thought their R&D efforts would remain stable or increase over the next few months, a 1.3 percentage-point drop from June. Employment and capital spending confidence increased slightly.

Should U.S. Revamp Patent System?

Congress is considering legislation that would fundamentally change the way U.S. patents are awarded. If the bills pass, the U.S. Patent and Trademark Office (PTO) would grant patents to those who file applications first rather than those who invent first, which is the current practice.

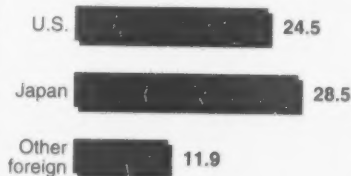
The proposed change is called "patent harmonization" because it would bring U.S. patent law into synch with patent laws of nearly every other country. As Robert Merges, professor of law at Boston Univ., describes it, "First-to-file provides settled rights immediately: Virtually as soon as you have filed, you know whether you have priority. First-to-invent, on the other hand, ensures fairness: The first actual inventor, rather than the one who is the first to rush to the patent office, receives the patent."

Proponents of patent harmonization claim the first-to-file method would be simpler and would eliminate the uncertainties associated with current U.S. law. Now, a patent award can be challenged after the fact by anyone who claims to have invented the product or process first. The resulting administrative "interference

proceedings" can be costly and lengthy. Only in relatively few cases have patents been revoked and re-awarded.

Last month, the Advisory Commission on Patent Law Reform assembled by former Commerce Secretary Robert Mosbacher recommended shifting to first-to-file, claiming that "more than 99.9% of the U.S. patent applications now being filed raise no dispute as to the identity of the first inventor."

Japan's Share of U.S. Patents Rises (Percent gain, 1988-1991)



Source: U.S. Patent and Trademark Office

The percentage gain in patents issued to Japanese and other foreign inventors has risen significantly.

Nevertheless, groups representing independent inventors, small businesses, and universities are opposing patent harmonization. They claim it would benefit big businesses and those with ample resources who would file patent applications quickly and often to protect potential inventions, even if the discoveries are neither totally new nor original. Individual inventors and those working for smaller companies would be harmed even if they did file first, the critics add, because competitors could file numerous modifications to the original patent in a "picket fence" strategy, forcing the true inventor to either sell the rights or engage in cross-licensing.

Supporters of patent harmonization argue that the benefits outweigh the risks. According to Harry Manbeck Jr., U.S. patent and trademarks commissioner, the "simplicity and certainty" of a first-to-file system "may well prove a significant advantage to small companies and independent inventors when contrasted with the complications, cost, and difficulties associated with proving that an inventor made an invention first."

And while first-to-invent is the

Auto Maker, National Lab Developing New Laser

Laser technician Scott Mitchell monitors a new solid-state laser as it cuts through a piece of steel. The laser is part of a \$3 million cooperative research and development agreement between Lawrence Livermore (CA) National Laboratory and General Motors Corp., Detroit.

The laser, to be used in cutting and welding sheet metal, will provide the auto maker with manufacturing flexibility, the developers say.

The laser beam will be transported through an optical fiber to multiple workstations and be focused tighter than existing lasers. Fiber-optic transport provides new flexibility, as present industrial gas lasers require mirrors to direct the beams.

The laser technology should reduce costs and require less maintenance, the developers say.

standard for U.S. patents, first-to-file is the "absolute requirement" for the rest of the world, says Robert Armistage, a vice president of the Upjohn Co., Kalamazoo, MI. "Few, if any, U.S. inventors operate in isolation from the global marketplace," he says. "Today, U.S. inventors simply do not have the opportunity to leisurely develop technology or extensively test their inventions before filing a patent application. Who can risk *not* being first-to-file?"

What many on both sides of the fence agree on is that the patent system needs reform. The percentage of U.S. patents issued to foreign competitors, principally Japan, has been rising, with nearly half the total going overseas (chart). Another problem has been the inadequacy of the PTO to decide claims in such fast-emerging, highly technical areas as biotechnology. Until recently, patent examiners had to search the massive files manually, resulting in issuance delays and infringement suits (litigation jumped 52% from 1980 to 1990).

While the installation of a computerized database and the hiring and training of specialized examiners have helped, the problems of international competitiveness have not abated.

Though Congress has not yet acted on the patent bills, the PTO quietly has been negotiating international harmonization since 1984 under the auspices of the World Intellectual Property Organization, a United Nations agency. In this effort, the PTO has sought to strengthen international protections for U.S. inventors.

For instance, the draft international agreement includes a 12-month worldwide grace period protecting inventors against loss of patent rights when they disclose their inventions prior to filing—an important facet for U.S. inventors, especially those in the university community who must "publish or perish" and have lost rights abroad due to early publication.

Over years of negotiation, Manbeck says, the U.S. has resisted international pressure to adopt the first-to-file requirement. But now, in order to get other needed international protections, "the price for obtaining a treaty" will be to adopt the first-to-file approach, he says.

—Ted Agres

Coal-Fired Power Plant Pares Pesky Pollutant

A worker inspects the lining of a flue section being installed at the coal-fired Drax Power Station in Yorkshire, England.

When completed in 1996, the flue-gas desulfurization plant will be the largest in the world. It is expected to remove 90% of sulfur dioxide emissions from the gas stream at the power station.

In operation, flue gas will pass through a large vessel called an absorber, which contains hundreds of nozzles that spray the gas with ground limestone and water. This causes the sulfur oxides in the flue gas to react chemically with the limestone, producing calcium sulfite.

The calcium sulfite is then reacted with oxygen to produce gypsum, which is bled away from the absorber and dried by centrifuges for use in wallboard, cement, and other products.

The power station is also fitting special burners to its boilers to reduce NO_x emissions.



Nanometer Cluster Collisions Spawn 'New Chemistry'

Nanometer-scale collisions of atomic clusters with solid substrates could play major roles in chemical process and materials science developments of the future. Supercomputer simulations conducted by Uzi Landman and his associates at Georgia Institute of Technology's School of Physics, Atlanta, suggest that such collisions at supersonic speeds could form the basis for new chemistries.

Studies by Landman's group involve clusters that create pressures up to 100,000 atm and temperatures as high as 4000 K when they hit a solid surface.

"We have very little knowledge about chemistry under these extreme conditions," Landman says. "Compounds that may not form under normal conditions may be produced under these circumstances."

In the latest work by Landman, Charles Cleveland, and Hai-Ping Cheng, programs were run to see

what could happen when microscopic droplets of a material are hurled against a hard surface. (The surface, Landman notes, could be a chemical, metal, or ceramic.) The optimum velocities for unique results were found to fall in a 2 to 5 km/sec range.

"In those cases, we've found that on impact the front atoms stop sud-

Supercomputer simulation shows what happens as an argon cluster crashes into a sodium chloride surface.

R&D SOFTWARE

HPLC Control Module

Revision 2.0 of the company's EZ-Chrom Chromatography Data System Software allows a user to set up and perform HPLC analyses and run concurrent HPLC and/or GC analyses from a PC, thus providing increased ease of use, higher productivity, and more efficient use of resources.

Shimadzu Circle 340

Wafer Level Reliability

The Wafer Level Reliability (WLR) test software package offers a fast, efficient way to test device quality and reliability parameters at the wafer level. WLR is designed for accelerated testing of specific failure mechanisms such as electromigration, oxide degradation, and MOS hot carrier injection.

Keithley Circle 341

Unlimited Mercury Intrusion

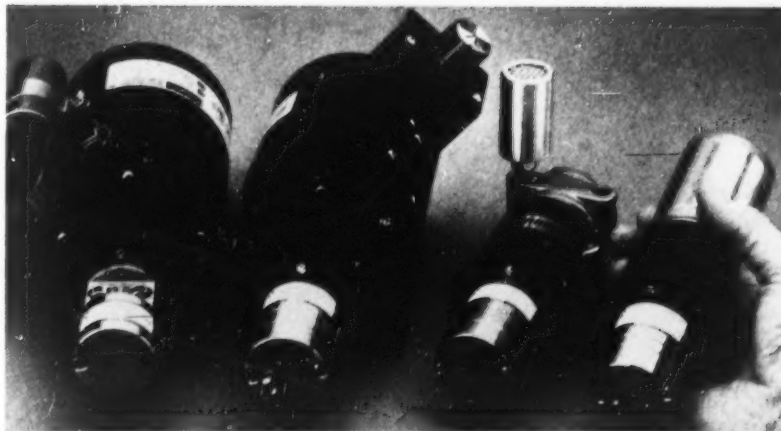
New control software extends the mercury intrusion volume of the company's Automated Mercury-Non-Mercury Porosimeter. This allows the penetrometer to be automatically refilled during an automated test. This refilling is done whenever necessary without any user intervention.

Porous Materials Circle 345

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